TOWN OF PLYMOUTH
WIND ENERGY FEASIBILITY STUDY

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Funded by

Massachusetts Technology Collaborative

Renewable Energy Trust

Community Wind Collaborative

Via E-mail

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To Whom It May Concern:

Subject: Community Wind Collaborative
Town of Plymouth Wind Energy Feasibility Study

Enclosed is our feasibility study report for wind energy generation at Plymouth, Massachusetts.

On behalf of R. W. Beck, Inc. and DNV Global Energy Concepts, Inc., we welcome this opportunity to support MTC in its Community Wind Collaborative.

If you have any questions or comments, you are welcome to contact Mia Devine at (206) 387-4257 or Paul Cleri at (508) 935-1846.

Very truly yours,

R. W. BECK, INC.

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NOTICE AND ACKNOWLEDGMENTS

This report, sponsored by the Renewable Energy Trust ("RET"), as administered by the Massachusetts Technology Collaborative ("MTC"), was prepared by the consulting team of R. W. Beck, Inc. ("R. W. Beck") and DNV Global Energy Concepts, Inc. ("DNV-GEC") at the direction of and for the benefit of MTC pursuant to Work Order Number 08-01 dated October 30, 2007 and the Master Services Agreement dated November 6, 2003. R. W. Beck, DNV-GEC, any of their affiliates, subsidiaries, directors, officers, employees, and sub-consultants make no warranties, expressed or implied, with respect to the report and accept no liability for consequential damages or loss, monetary or otherwise, suffered due to decisions made based upon this report. The opinions expressed in this report do not necessarily reflect those of MTC or the Commonwealth of Massachusetts (the "Commonwealth"), and reference to any specific product, service, process, or method does not constitute an implied or expressed recommendation or endorsement of it.

ABSTRACT

This feasibility study investigates the feasibility, planning, and development issues of wind energy generation at Plymouth, Massachusetts ("Plymouth"). This feasibility study considers a single wind energy plant concept located at Plymouth's wastewater treatment plant (the "WWTP"), analyzes wind data from the Plymouth County Sheriff's Office and Correctional Facility site as collected by the University of Massachusetts Renewable Energy Research Laboratory ("RERL"), performs a feasibility assessment, identifies predevelopment tasks, identifies specific site preparation work, evaluates certain project economics, identifies technical data to prepare anticipated permits and approvals applications, considers community electric loads, considers electric interconnect to the WWTP, provides photo simulations, considers environmental receptors, and identifies certain conclusions and observations regarding the feasibility of the proposed project.

The following list of keywords is for RET's project database and website search feature.

Keywords:

- Plymouth
- Feasibility
- Planning
- Development
- Wind
- Energy
- R. W. Beck, Inc.
- DNV Global Energy Concepts, Inc.
- Wind Turbine Generator
- University of Massachusetts Renewable Energy Research Laboratory, RERL
- Project Economics
- Permits and Approvals
- Electric Loads
- Electric Interconnect
- Wastewater Treatment Plant, WWTP
- Photo Simulations
- Environmental Receptors
- Renewable
- Massachusetts Technology Collaborative, MTC

EXECUTIVE SUMMARY

MTC retained the consulting team of R. W. Beck and DNV-GEC (collectively and individually, the "Consultant") to conduct a feasibility study of implementing wind energy generation at Plymouth's WWTP. This feasibility study has been performed in close cooperation with the Plymouth Energy Committee (the "Committee").

For an initial screening, the Consultant evaluated several potential sites in Plymouth for wind energy development, and summarized these results in a report titled "Town of Plymouth Wind Energy Screening Analysis, Revision 1", dated December 19, 2007 (the "Screening Analysis"). The Screening Analysis identified the WWTP, the South High School, and the Indian Brook Elementary School as having the most promise for wind energy development in Plymouth. The Committee asked the Consultant to focus this feasibility study on development at the WWTP site using two, megawatt-class wind turbines electrically connected to the WWTP to displace its electric load as well as export excess energy under the Commonwealth's net metering regulations and laws. The Committee and MTC further directed the Consultant to assume the use of a General Electric ("GE") 1.5sle wind turbines at a hub height of 80 meters ("m") as the focus of certain analyses in this feasibility study. The Consultant made follow-up site visits to Plymouth and the WWTP site during May and June 2008 and also received informative assistance from the Committee and MTC during this period.

The objective of this feasibility study is to: (a) identify a conceptual wind energy plant design; (b) perform feasibility and certain predevelopment analyses; (c) identify site preparation work that could be completed in advance of project development; (d) perform certain analyses needed to finalize the wind turbine site; (e) evaluate certain project economics; (f) identify certain technical data to be used for certain permit and approval applications; and (g) provide certain opinions regarding the feasibility of the proposed project. On the basis of the Consultant's level of review and the documentation reviewed, this feasibility study supports the following conclusions:

- The WWTP site appears to be a viable location for a wind energy plant.
- The Consultant has identified no problematic technical issues regarding construction or transportation of equipment to the WWTP site.
- Two wind turbines can be electrically interconnected to the WWTP's electric distribution system to export power to the NSTAR system as well as supply the intermittent needs of the WWTP.
- The spacing of two megawatt-size wind turbines on the WWTP property is relatively close compared to industry best practices, which may result in high wake losses and turbulence on the downwind turbine. The installation of a single turbine or two smaller, sub-megawatt-size wind turbines may be more appropriate for the site.
- While there will be a visual impact in Plymouth, the Consultant has identified no other problematic environmental issues. The Consultant recommends further environmental impact analysis particularly with regard to Plymouth's Core Habitat designation.
- The proposed turbine locations identified in this report should be able to meet the requirements of the Plymouth Bylaw with regard to setback and noise, and there are turbines available that meet the requirements under the Plymouth Bylaw with regard to height and noise.

Section 1
INTRODUCTION

This feasibility study is in response to the scope of work negotiated with MTC which is described more fully in a professional services agreement with MTC. This report (the "Report") identifies issues raised during preparation of the feasibility study and is submitted to MTC for its review and use. All statements in the Report concerning the various technical issues are on the basis of information provided to us by Plymouth, MTC, RERL, equipment vendors, and those assumptions identified in this Report.

The Committee has selected Plymouth's WWTP site as the focus for a potential development location. This study and Report focuses solely on this area of Plymouth. Additionally, the Committee asked that this study initially consider a wind energy plant comprised of two wind turbines.

In support of the Committee, the objective in this Report is to prepare a wind energy planning and development study intended to provide sufficient information to support local decision-making regarding whether or not to proceed with a wind development project. The study addresses technical, environmental, and regulatory aspects of the proposed wind energy plant to:

- Identify conceptual wind energy plant configuration;
- Evaluate technical feasibility of conceptual wind energy plant configuration;
- Understand environmental and community impacts as well as community acceptance;
- Develop capital and operating cost assumptions;
- Document and evaluate permitting and approvals aspects; and
- Estimate wind energy production levels for conceptual wind energy plant.

The study is not intended to identify and evaluate project ownership and financing options (e.g. local bonding, public-private partnerships) nor does this study include a project pro forma analysis. MTC is separately preparing a generic evaluation of community wind ownership and financing options.

As previously indicated in this Report, the Consultant had earlier performed a screening analysis to identify and evaluate factors that would make it infeasible, inappropriate, or overly difficult to develop a wind energy project in Plymouth. The Consultant had examined aspects of wind energy development and had assessed how these factors would impact a proposed wind turbine installation. The Consultant's analysis had included an inspection of the WWTP site and vicinity and discussions with the Committee. The Consultant's screening analysis determined that there were no technical impediments to going forward with a wind energy project at the WWTP site.

This feasibility study is intended to extend the results of the earlier screening analysis to a conceptual level of project feasibility, planning, and predevelopment topics. Accordingly, the scope of this study and Report includes the following:

1. Evaluate technical issues related to development of the project, including: site characteristics; electrical infrastructure; neighborhood impacts; environmental impacts; wind turbine location; and geotechnical topics.

2. Review and evaluate wind data collected on site by other parties, including correlation with appropriate long-term wind data sources, to the extent feasible, refine estimates of the wind resource at the project site; and develop a wind resource profile for use in estimating annual electricity production and the allocation of generated electricity between on-site loads and exports to the utility system.
3. Characterize WWTP electric loads, including diurnal and seasonal variability if possible, and understand the potential for use of wind-generated electricity at the WWTP.
4. Estimate turbine annual energy production and the allocation of generated electricity among WWTP loads and exports to the grid and estimate predicted life-cycle productivity of the wind turbine.
5. Identify likely required permits and approvals, including federal, state, local, and utility interconnection approvals, identify additional activities that must be completed prior to filing for permits and approvals, and estimate the timeframe for securing same.
6. Prepare photo-simulations depicting a two-wind turbine project from up to four vantage points in Plymouth.

Unless referring to other sources that specifically use traditional British/American-based English units, in this Report data and results are provided in Système International ("SI") units to be consistent with the raw data available and to be consistent with wind industry standard practice.

Section 2
SITE PROFILE

Plymouth

Plymouth, which was incorporated in 1670, is a bedroom/tourist community located in southeastern Massachusetts, northwest of Cape Cod, which is bordered by Kingston to the north, the Cape Cod Bay to the east, Bourne to the south, and Carver and Wareham to the west. Plymouth is approximately 60 kilometers ("km") south-southeast of Boston, Massachusetts; 65 km east of Providence, Rhode Island; and 305 km northeast of New York City. Refer to Figure 1 below.

Figure 1 – Plymouth, Massachusetts

Site and Existing Conditions

The WWTP site, which occupies approximately 100 acres of Town-owned land, is located southeast of Camelot Drive approximately 4 km southeast of Plymouth center; it is between Massachusetts Route 3 and Long Pond Road. The WWTP site is approximately 7 km from the Plymouth Municipal Airport.

Figure 2 - The WWTP Site and Surrounding Area

Note that the proposed turbine locations are indicated in Section 3 of this Report. As shown in Figure 2 above, visible in the upper left corner are several buildings and structures scattered on the WWTP site devoted to pumping, maintenance, water treatment, and other water supply-related activities. Additionally, the northern corner of the WWTP site is comprised of infiltration ponds.

Visible in the middle of Figure 2, in the southeastern half of the WWTP site, is the general area proposed for the wind turbines where the wind turbine locations are approximately 150 m to 165 m southwest of the WWTP facilities. The proposed locations are separated from the WWTP buildings and infiltration ponds by a sand pit which is approximately 150 m wide. The proposed wind turbine locations are located within a forest of coniferous and deciduous trees. The surrounding trees are estimated to be 10 m tall. The elevation of the forested area is approximately 45 m above mean sea level ("amsl") and approximately 20 m above the main portion of the WWTP. This area is relatively flat with a gradual downward slope to the southeast. Because of the southwest to northeast orientation of the available land, there are limited well-exposed areas that offer turbine locations perpendicular to the prevailing southwest wind direction.

Visible in bottom middle and lower right corner of Figure 2 are the nearest residential neighbors (receptors) to the WWTP site, which are approximately 1250 m southeast of the nearest proposed turbine location.

Electric Infrastructure

Plymouth is within the regional NSTAR Electric distribution system. Plymouth purchases power from NSTAR for its municipal buildings and loads.

The WWTP site is supplied from a single overhead 23 kilovolt ("kV") distribution line from the NSTAR distribution system to provide power to the WWTP site. The WWTP is connected at the end of the overhead distribution circuit. The connection from the overhead system to the WWTP is through an underground cable connected to the overhead system through a fused switch mounted on the pole at the end of the overhead circuit. The cable runs from the pole, under the parking lot to a 1500 kilovolt-ampere ("kVA"), 23 kV-480 volt ("V") pad mounted transformer and meter owned by NSTAR located adjacent to the WWTP main building. The low voltage side of the transformer supplies the main 480 V switchboard in the WWTP, and electricity is distributed from that switchboard to the equipment and loads in the WWTP.

The capacity of NSTAR's local distribution system in the vicinity of the WWTP site as well as the distribution system feeding other municipal buildings is unclear. When the interconnection application process with NSTAR is commenced, one of the first issues will be to determine that sufficient ampacity (i.e., electrical current carrying capacity) exists in the local distribution system to carry excess power or exported power generated from a wind turbine or multiple wind turbines at the WWTP site. Based on typical electrical distribution system design it is likely that the existing overhead conductors will be of sufficient ampacity to carry the electrical output of the two wind turbines proposed for this project.

Additionally the NSTAR studies conducted as part of the interconnection application process will need to determine whether the local distribution system could absorb a fluctuating generating power output of up to 3 megawatts ("MW") exported to it without causing instability on the distribution system. The level of power export to the NSTAR system without causing instability may be less than the planned 3 MW capacity of the proposed project.

Accordingly until the interconnection application process is commenced and NSTAR is able to provide information regarding the capacity of its local distribution and analyze the impact of added generation on the local distribution system, the Consultant believe the prudent course is to leave flexibility in the project development in the event that it is limited to a single wind turbine installation at the WWTP site as a result of NSTAR system impact studies.

For further detail regarding the NSTAR system/grid, refer to the discussion of electric interconnect in Section 4 in this Report.

Electric Load Profile of the WWTP

Limited recent electric utility billing data (January 2005 through April 2008) provided by the operator of the WWTP, Veolia Water North America ("Veolia"), indicate that the WWTP's peak electric demand ranges from 503 kilowatts ("kW") to 774 kW and that monthly electric energy usage ranges from approximately 101,000 kilowatt-hours ("kWh") to 316,000 kWh. Monthly energy usage at the WWTP appears to have increased from 2005 to 2008 with usage ranging from approximately 178,000 kWh/month to 317,000 kWh/month. This data suggests an average electric load of approximately 138 kW to 433 kW.

Table 1 summarizes available WWTP energy usage data – from 2005 through April 2008.

Table 1
WWTP Historic Electric Energy Usage

Year	Type	January	February	March	April	May	June	July	August	September	October	November	December	Type Average	Total
2005															
	DEMAND, kW	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	--	
	ENERGY														
	Peak, kWh	27567	30587	31810	53276	47624	70551	65982	61292	63394	64665	33625	29778	48346	--
	Low – A, kWh	55323	63657	63629	46736	30174	45924	44578	39498	42131	42245	63920	59243	49755	--
	Low – B, kWh	103542	108556	117033	124340	85894	150141	125840	119770	133299	115882	116175	101515	116832	--
	Total, kWh	186432	202800	212472	224352	163692	266616	236400	220560	238824	222792	213720	190536	214933	2579196
2006															
	DEMAND, kW	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	--	
	ENERGY														
	Peak, kWh	27525	28263	30490	53023	57563	57563	52203	62548	77334	50087	33395	36707	47225	--
	Low – A, kWh	56345	60112	64055	43180	36634	36634	33082	40490	49398	31509	60079	76493	49001	--
	Low – B, kWh	98914	101801	122151	111421	108195	108195	106331	119274	146652	96628	101526	134960	113004	--
	Total, kWh	182784	190176	216696	207624	202392	202392	191616	222312	273384	178224	195000	248160	209230	2510760
2007															
	DEMAND, kW	NA	NA	NA	671.0	712.0	774.0	601.0	722.0	524.0	513.0	525.0	503.0	--	
	ENERGY														
	Peak, kWh	41498	32791	71911	64214	85466	59332	65694	53821	67684	61725	44575	25681	56199	--
	Low – A, kWh	81480	66043	76903	43465	56520	39414	42540	37469	42237	35871	63045	58633	53635	--
	Low – B, kWh	151870	138574	167386	130281	174790	113150	119646	110502	135119	117588	136460	92086	132288	--
	Total, kWh	274848	237408	316200	237960	316776	211896	227880	201792	245040	215184	244080	176400	242122	2905464
2008															
	DEMAND, kW	523.0	527.0	616.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	--	--
	ENERGY														
	Peak, kWh	33652	36533	41643	49258	NA	NA	NA	NA	NA	NA	NA	NA	40272	--
	Low – A, kWh	69189	71048	45004	32093	NA	NA	NA	NA	NA	NA	NA	NA	54334	--
	Low – B, kWh	134903	134243	103889	99561	NA	NA	NA	NA	NA	NA	NA	NA	118149	--
	Total, kWh	237744	241824	190536	180912	NA	NA	NA	NA	NA	NA	NA	NA	212754	851016

Notes:

1. *All data on the basis of billing months.*
2. *NA = Not available*

The average monthly energy usage for calendar year 2007 was 242,122 kWh. On the basis of a fairly constant electric load profile, 2007's monthly energy usage equates to an average levelized load of approximately 331.7 kW.

Electricity for the WWTP is purchased from NSTAR under Rate 24 SEMA, which is a sub-category of NSTAR's Large General Time-of-Use G-3 Rate, which is approved as No. 332F by the Massachusetts Department of Telecommunication and Energy. Rate 24 is for NSTAR customers with a load that is greater than 500 kW during at least twelve consecutive billing months. Rate 24 has a peak and two off-peak periods, identified as Peak Load, Low Load A, and Low Load B. Peak Load is from 9:00 a.m. to 6:00 p.m., Monday through Friday, during Eastern Daylight Time; and from 4:00 p.m. to 9:00 p.m., Monday through Friday, during Eastern Standard Time. Low Load B is from 10:00 p.m. to 7:00 a.m., Monday through Friday, and all hours on Saturday and Sunday, during both Eastern Daylight Time and Eastern Standard Time. Low Load A includes all hours not included in Peak Load and Low Load B. Figure 3 depicts the WWTP's energy usage patterns by peak and off-peak periods.

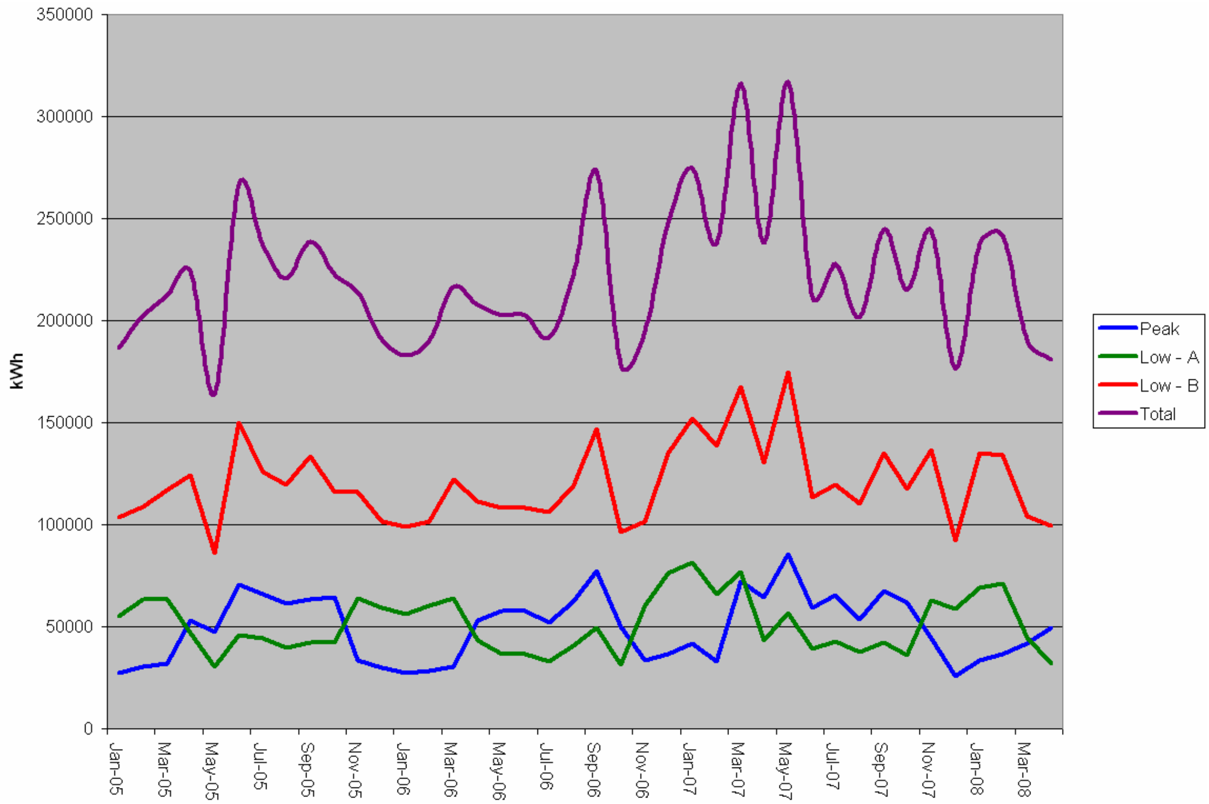


Figure 3 - WWTP Electric Energy Usage Profile

The data indicates that there is a large enough base electric load at the WWTP to support the concept of a wind energy plant displacing energy needs at the WWTP. Further discussion follows in Section 4 of this Report.

Section 3
WIND RESOURCE ASSESSMENT AND ENERGY ESTIMATE

Wind data from a meteorological ("met") tower located at the Plymouth County Sherriff's Office and Correctional Facility were furnished to the Consultant for the purposes of estimating the long-term wind resource and expected annual energy output for several proposed wind power project configurations at the Plymouth Water Treatment Facility. RERL installed the meteorological tower in May 2007 and has managed the data collection since. The RERL provided to the Consultant validated ten-minute meteorological data from May 2007 through February 2008 and raw ten-minute data from March 2008 through April 2008.

The Consultant visited the met tower in October 2007. The tower appeared to be in good condition and GEC documented tower and sensor information. The tower is instrumented with four anemometers, two each at 50 m and 38 m above ground level ("agl"). The anemometers at each level are mounted on 1.4-m (54-inch) side-mount booms, one east and one west of the tower. The tower is also instrumented with two wind vanes, one each at 50 m agl and 38 m agl. The wind vanes are mounted on the same type of boom as the anemometers and are mounted on the north side of the tower. The dataset used for this feasibility study includes data from May 10, 2007, through April 30, 2008.

Figure 4 illustrates the approximate met tower location, which is in a clearing approximately 1.5 km northwest of the proposed wind project site at the WWTP. The tower is sited within a cornfield with surrounding coniferous and deciduous trees and buildings of approximately 8 m to 10 m in height at a distance of approximately 150 m from the met tower. There are no other significant obstructions between the met tower and the proposed wind project site at the WWTP, and the two sites are located at approximately the same elevation. The met tower location and proposed wind turbine sites have similar exposures in the prevailing wind direction.

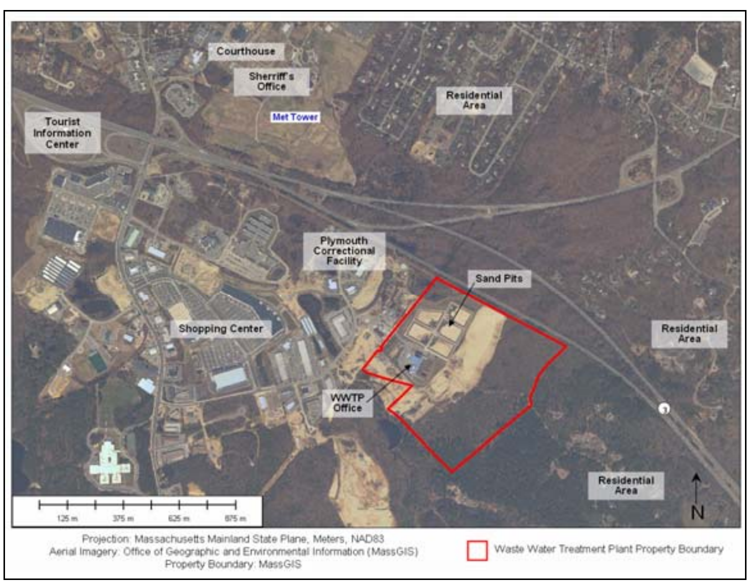


Figure 4 - Met Tower Location in Relation to WWTP Site

Data Review and Validation

The Consultant reviewed the validated data set provided by RERL and quality checked the raw dataset using industry standard techniques and best practices. In addition to some periods of missing data, the Consultant removed a few hours of wind speed data to account for sensor icing and other irregularities. Table 2 summarizes the valid data recovery percentage as a percent of calendar time, after the Consultant's validation review. The monthly data recovery of 50-m wind speeds is very good at 93 percent or better, with the exception of May 2007, which is a partial month, and September 2007, which experienced a significant amount of data loss due to a malfunction of the primary anemometer. Since the 38 m anemometers remained functional during most of September, the Consultant extrapolated this data to 50 m using the measured diurnal wind shear profile during the valid portion of the month. This brings the 50 m data recovery rate up to 83 percent for the month of September.

Table 2
Sensor Valid Data Recovery

	Anemometers				Wind Vanes	
	50 m E	**50 m W**	**38 m E**	**38 m W**	**50 m N**	**38 m S**
May 2007	71%	71%	71%	71%	71%	71%
June	100%	100%	100%	100%	100%	100%
July	100%	100%	100%	100%	100%	100%
August	98%	98%	98%	100%	100%	100%
September	42%	42%	42%	83%	83%	83%
October	100%	100%	99%	100%	100%	100%
November	99%	99%	99%	100%	99%	100%
December	93%	93%	89%	90%	93%	90%
January 2008	100%	100%	99%	99%	100%	99%
February	93%	93%	93%	94%	93%	93%
March	100%	100%	100%	100%	100%	100%
April	100%	100%	100%	100%	100%	100%
Overall	91%	91%	91%	95%	95%	95%

Wind Data Summary

A monthly summary of the 50 m and 38 m measured wind speeds is presented in Table 3. The table indicates an average 50-m wind speed of 5.6 meters per second ("m/s") measured during the period of record.

Table 3
Measured Monthly Average Wind Speeds, m/s

	50 m Height	38 m Height
May 2007 [(1)]	5.6	5.2
June	5.4	5.1
July	4.8	4.4
August	4.8	4.4
September [(2)]	5.3	4.9
October	5.3	4.8
November	6.2	5.6
December	5.8	5.3
January 2008	6.1	5.6
February	6.0	5.5
March	6.4	6.0
April	5.1	4.7
Overall	**5.6**	**5.1**

Notes:

1. *Less than 90 percent data recovery rate.*
2. *Less than 60 percent original data recovery rate, 38 m height was used to extrapolate 50 m height, resulting in 83 percent data recovery rate.*

The average monthly diurnal pattern of the 50-m winds during the period of record is illustrated in Figure 5. As shown in the figure, the magnitude of the wind speeds during the winter months is greater than during the summer months; however, the diurnal patterns of the wind speeds do not vary significantly from month to month. These observations are based on only the measured dataset and may not necessarily represent the long-term pattern.

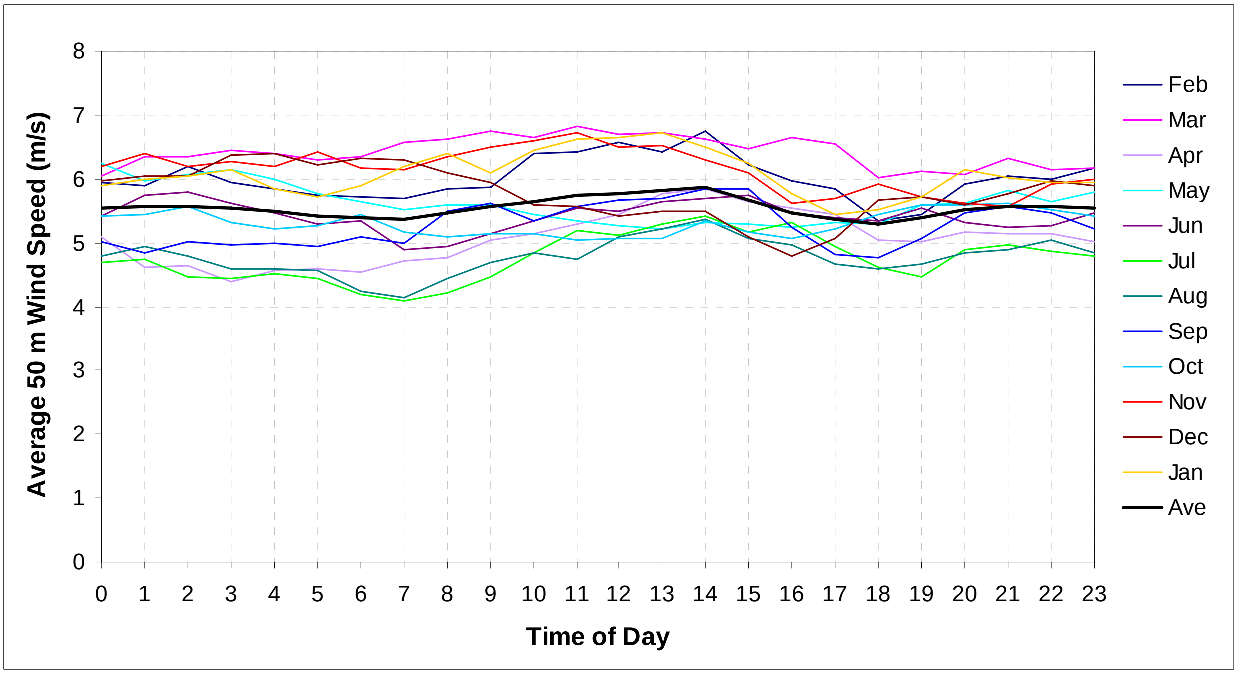


Figure 5 - Diurnal Wind Speed Pattern by Month

Wind Direction

A wind rose graph is a visual representation of the predominant wind directions of a site and is calculated based on the percent of total time and percent of total theoretical energy available in the wind for each direction sector. The wind rose based on data measured at the met tower site is shown in Figure 6. As shown, the predominant direction during the period of record was from the southwest. The wind rose graph is created from concurrent wind speed and direction data and is therefore limited to hours where both wind speed and direction are available. While these results are based on only 12 months of data, the results are consistent with the long term (12-year) record from the Plymouth Municipal Airport weather station as shown in Figure 7.

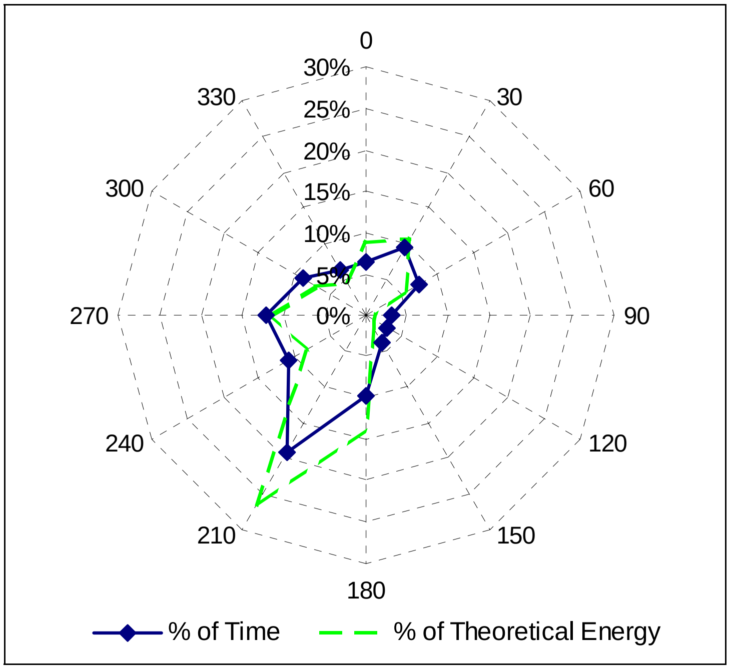


Figure 6 - Measured Wind Rose from May 2007 to April 2008

In comparison, Figure 7 is the measured wind rose from the Plymouth Municipal Airport weather station from July 1996 to March 2008; it also indicates a primary southwest wind direction, in both frequency of time and energy.

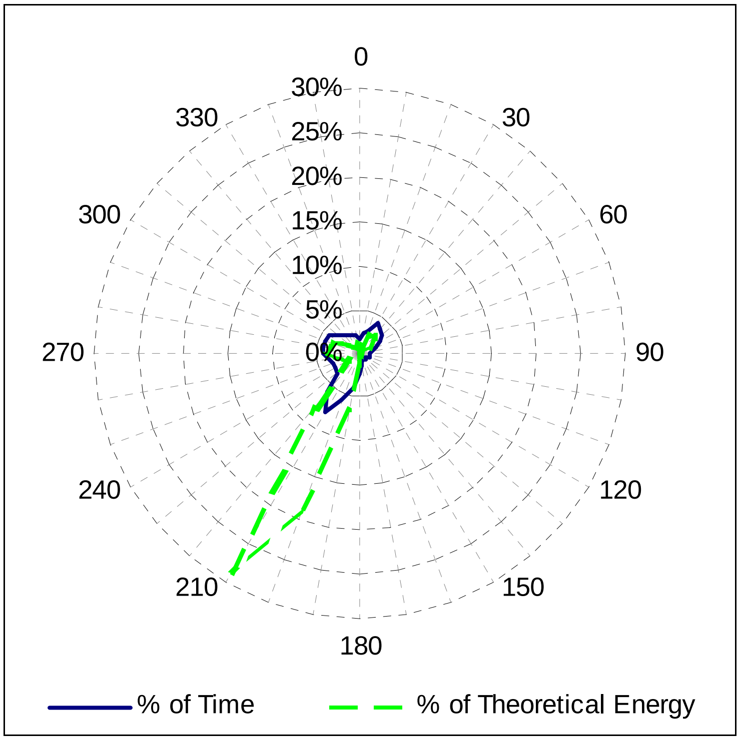


Figure 7 - Measured Wind Rose from Plymouth Municipal Airport

Turbulence Intensity

Turbulence intensity ("TI") is a relative indicator of the turbulence characteristics of a site and is used to determine the type of wind turbine that may be suitable for the site. TI is calculated as the ratio of the wind speed standard deviation to the wind speed. Turbulence decreases with height above ground level; consequently, TI at the upper measurement levels on the tower (50 m) were extrapolated to the turbine hub height (80 m) by applying wind shear to calculate a hub height wind speed while keeping the standard deviation constant. This method has been shown to reliably predict the decrease in turbulence with height across measurement levels on towers, and should produce reasonable predictions of the hub height turbulence.

The average measured TI by direction at the upper measurement levels and the estimated TI by direction at hub height are presented in Table 4.

Table 4
Mean Turbulence Intensity by Direction Sector

Direction Sector (°)	Height agl	
	50 m	80 m
0	0.17	0.15
30	0.17	0.16
60	0.17	0.16
90	0.21	0.19
120	0.19	0.18
150	0.16	0.14
180	0.16	0.14
210	0.16	0.13
240	0.15	0.14
270	0.18	0.15
300	0.19	0.16
330	0.18	0.16
Average	**0.17**	**0.15**

TI by wind speed for the measured height and turbine hub height is shown in Table 5.

Table 5
Mean Turbulence Intensity by Wind Speed

Wind Speed, m/s	Height agl	
	50 m	80 m
1	0.45	0.47
2	0.24	0.25
3	0.17	0.17
4	0.15	0.15
5	0.15	0.14
6	0.15	0.13
7	0.16	0.12

Table 5
Mean Turbulence Intensity by Wind Speed

Wind Speed, m/s	Height agl	
	50 m	**80 m**
8	0.17	0.12
9	0.18	0.13
10	0.18	0.14
11	0.18	0.15
12	0.17	0.15
13	0.17	0.15
14	0.18	0.15
15	0.17	0.14
16	0.17	0.15
17	0.16	0.15
18	0.17	0.15
19	0.16	0.14
20	0.16	0.15
21	0.15	0.14
22	0.16	0.14
23	0.14	0.13
24	-	0.13
25	-	0.14
>25	-	.09
Weighted Average (>4 m/s)	**0.16**	**0.13**

TI by wind speed is also shown for the upper measurement level in Figure 8; the plot illustrates the average TI for all wind speeds as well as the average TI for each wind speed bin. The overall average TI of the met tower site is approximately 0.15 at 80 m.

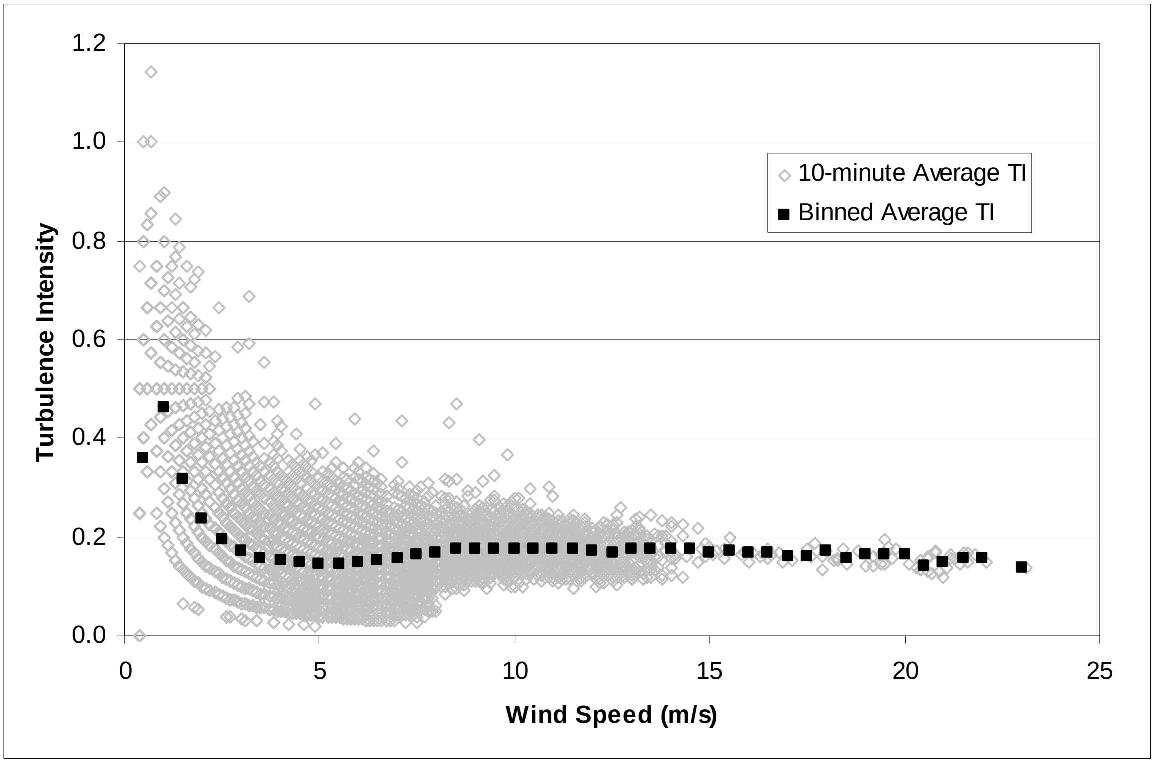


Figure 8 - Average Turbulence Intensity by Wind Speed, 50 m height

The International Electrotechnical Commission ("IEC") defines different categories of wind turbines based on the mean TI at 15 m/s for which the turbine model is designed to operate. As shown in Table 5, the estimated mean TI at 15 m/s is 0.14 at an 80 m height above ground level, which is in the mid to high range of acceptable TI levels. The relatively high TI value, combined with high wind shear (discussed in a later section), may cause turbine suitability concerns. The turbine manufacturer will need to verify site suitability once the Town enters discussion with a specific turbine supplier.

Long-Term Representativeness

Data collected from the Plymouth County Sherriff's Office met tower may represent a period of relatively high or low wind speeds compared to the long-term average. To determine the representativeness of the data collection period and make adjustments to long-term conditions, the Consultant established a correlation to a long-term reference site. The Consultant obtained data from the Plymouth Municipal Airport, located approximately 7 km west-southwest of the Plymouth County Sherriff's Office met tower. Data were collected at a height of 10 m above ground level and were available since July 1996. Over the past few years, the U.S. National Weather Service and the U.S. Federal Aviation Administration ("FAA") have been converting Automated Surface Observation System ("ASOS") station anemometry to sonic anemometers. This type of instrumentation change can affect the long-term consistency of the data. The Plymouth Municipal Airport station anemometer was converted to a sonic anemometer in October 2005. No adjustments were made to the airport data to account for the change in

equipment; however, the potential impact on estimated energy production is included in the uncertainty analysis.

The Consultant performed a linear regression analysis using concurrent monthly average wind speeds from the met tower and from the airport for the overlapping period of record. The data from the two sites are relatively well-correlated with an R-squared value of 0.80. The daily correlation between the sites was similar. The results of the monthly correlation analysis are shown in Figure 9.

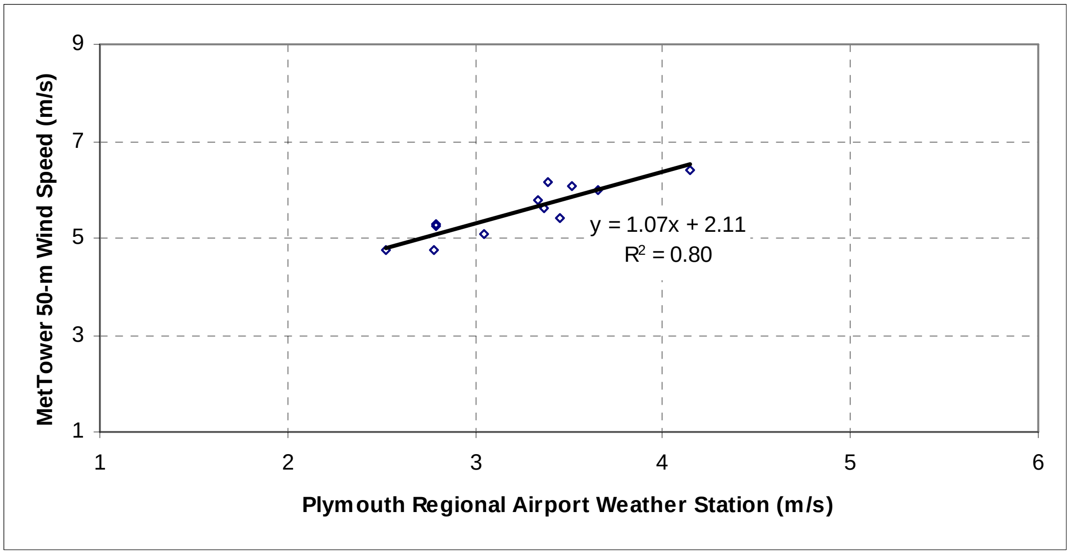


Figure 9 - Linear Regression: Monthly Average Wind Speed from May 2007 through April 2008

Based on the findings described above, the Consultant adjusted the one year of met tower data on a monthly basis using long-term monthly adjustment factors derived from the long-term Plymouth Municipal Airport data set. The adjustment factor is multiplied by the 50 m wind speed on a per record basis to produce a long-term 50 m height wind speed at the met tower location. The monthly adjustment factors are presented in Table 6. The values in this table represent the ratio between the reference site's long-term average wind speed for each month, and the reference site's monthly average wind speed during the period of record. For example, in January 2008, the adjustment factor of 1.11 in Table 6 indicates that January's long-term average wind speed is 11 percent higher than the average wind speed in January 2008. Therefore all of the hub-height wind speed records in January 2008 are multiplied by 1.11.

Table 6
Long-Term Wind Speed Analysis – Plymouth Municipal Airport

Year	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997	4.5	4.3	4.4	3.7	4.0	3.1	3.3	2.3	3.1	2.7	4.0	3.6
1998	4.0	4.2	4.2	3.5	3.7	3.4	2.8	2.5	2.8	3.6	3.2	3.3
1999	3.9	3.8	4.8	3.8	3.0	3.1	3.0	2.6	1.9	2.4	3.5	3.3

2000	4.3	3.8	3.9	4.3	2.5	3.4	2.9	2.8	3.0	3.1	3.4	4.0
2001	2.8	4.1	4.4	3.3	3.3	2.9	2.9	2.6	3.1	3.5	3.2	3.1
2002	3.5	3.8	3.9	3.8	3.9	3.5	3.4	3.2	3.2	3.3	4.3	4.1
2003	4.4	4.2	3.8	4.0	3.0	2.3	2.4	2.6	2.4	3.3	3.3	4.3
2004	4.1	3.8	4.4	4.1	3.5	3.2	3.0	3.1	3.0	3.6	3.4	3.7
2005	4.0	3.5	3.8	3.7	4.1	3.4	3.3	2.8	2.8	3.9	3.1	3.2
2006	3.8	4.2	3.6	3.6	4.0	3.0	3.0	2.7	2.5	3.6	2.8	3.4
2007	3.9	4.2	4.6	4.1	3.4	3.5	2.8	2.5	2.8	2.8	3.4	3.3
2008	3.5	3.7	4.1	3.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ave	3.9	3.9	4.2	3.7	3.5	3.2	3.0	2.7	2.8	3.2	3.4	3.6
Met Tower Period of Measurement Average												
2007	N/A	N/A	N/A	N/A	3.4	3.5	2.8	2.5	2.8	2.8	3.4	3.3
2008	3.5	3.7	4.1	3.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Long-Term Adjustment Factor												
	1.11	1.08	1.00	1.22	1.04	0.92	1.07	1.07	1.00	1.16	1.01	1.07

***Notes**:*
1. NA = Not available.

Overall, the adjustment factors result in an aggregate long-term upward adjustment of 6 percent on the met tower wind speed. This adjustment resulted in an increase of the 50-m annual measured wind speed from 5.55 m/s to 5.90 m/s, representing the long-term annual average wind speed at the Plymouth County Sherriff's office site. The long-term adjustment of 6 percent is slightly larger than typical based on the Consultant's experience with other wind projects in New England; however, the Consultant also evaluated the long-term record at the New Bedford Airport weather station, which indicated a similar trend as at the Plymouth Municipal Airport. The potential impact of the long-term adjustment on estimated energy production is included in the uncertainty analysis.

Wind Shear and Estimated Hub-Height Wind Speeds

Wind speeds generally increase with height above ground level. To estimate the wind speeds at the proposed wind turbine hub heights of up to 80 m based on the met tower measurement height of 50 m, the following method was used. Wind shear was calculated using the 50 m and 38 m wind speed measurements, and this relationship was then applied to extrapolate from 50 m to the turbine hub height. To reduce tower-shadow error, wind shear was only calculated when each anemometer was clear of significant tower wake. Data when wind speeds at any level were less than 4 m/s were also excluded from the wind shear analysis.

The wind shear exponent, α , is calculated using the power law method of wind shear calculation,

$$\alpha = \frac{\ln\left(\frac{V(z)}{V_R}\right)}{\ln\left(\frac{z}{z_R}\right)} \qquad \text{Eqn. 1}$$

where VR is the reference wind speed, z is the proposed turbine hub height, V(z) is the wind speed at height z, and zR is the reference height. Table 7 shows the wind shear exponents calculated from the measured data.

Table 7
Vertical Wind Shear Exponent Calculation from the Measured Data

Hour	1	2	3	4	5	6	7	8	9	10	11	12	Ave
0	0.40	0.40	0.39	0.50	0.41	0.42	0.45	0.48	0.40	0.46	0.45	0.44	0.44
1	0.39	0.43	0.40	0.53	0.45	0.46	0.49	0.49	0.42	0.48	0.43	0.43	0.45
2	0.41	0.44	0.41	0.52	0.43	0.46	0.47	0.50	0.44	0.49	0.44	0.45	0.45
3	0.42	0.42	0.40	0.52	0.39	0.45	0.47	0.49	0.43	0.48	0.43	0.43	0.44
4	0.42	0.43	0.38	0.51	0.43	0.44	0.49	0.49	0.45	0.47	0.46	0.42	0.44
5	0.39	0.44	0.43	0.49	0.39	0.39	0.44	0.47	0.45	0.49	0.46	0.40	0.43
6	0.37	0.45	0.42	0.41	0.32	0.32	0.32	0.36	0.40	0.45	0.45	0.41	0.39
7	0.39	0.38	0.36	0.33	0.22	0.25	0.21	0.21	0.26	0.39	0.40	0.39	0.33
8	0.37	0.31	0.27	0.25	0.17	0.22	0.20	0.17	0.20	0.30	0.30	0.37	0.27
9	0.27	0.27	0.27	0.26	0.17	0.19	0.16	0.16	0.20	0.25	0.23	0.30	0.23
10	0.25	0.22	0.25	0.28	0.15	0.18	0.14	0.12	0.18	0.23	0.24	0.28	0.21
11	0.23	0.23	0.21	0.25	0.15	0.18	0.13	0.11	0.18	0.21	0.21	0.28	0.20
12	0.25	0.24	0.22	0.26	0.13	0.19	0.13	0.13	0.16	0.22	0.22	0.28	0.21
13	0.23	0.25	0.24	0.26	0.11	0.17	0.16	0.14	0.21	0.23	0.24	0.28	0.21
14	0.23	0.25	0.23	0.25	0.15	0.19	0.20	0.17	0.22	0.24	0.25	0.28	0.22
15	0.27	0.27	0.24	0.29	0.16	0.22	0.20	0.20	0.22	0.28	0.28	0.33	0.25
16	0.31	0.32	0.26	0.32	0.20	0.25	0.23	0.24	0.26	0.33	0.33	0.36	0.28
17	0.34	0.37	0.31	0.35	0.25	0.28	0.25	0.29	0.32	0.38	0.37	0.41	0.33
18	0.38	0.42	0.36	0.40	0.32	0.31	0.30	0.38	0.42	0.38	0.40	0.48	0.38
19	0.38	0.40	0.37	0.44	0.42	0.36	0.36	0.40	0.45	0.41	0.41	0.46	0.40
20	0.39	0.41	0.40	0.45	0.42	0.38	0.42	0.45	0.46	0.41	0.41	0.47	0.42
21	0.38	0.43	0.37	0.49	0.42	0.39	0.44	0.49	0.41	0.43	0.48	0.47	0.43
22	0.40	0.41	0.37	0.48	0.44	0.40	0.45	0.48	0.40	0.45	0.48	0.51	0.44
23	0.41	0.41	0.40	0.50	0.43	0.43	0.45	0.45	0.44	0.42	0.44	0.47	0.44
Overall	**0.34**	**0.35**	**0.33**	**0.37**	**0.30**	**0.31**	**0.31**	**0.32**	**0.32**	**0.37**	**0.37**	**0.39**	**0.34**

The calculated wind shear values are higher than expected. Based on its experience, the Consultant expects shear exponents of approximately 0.20 to 0.30 for low forests and suburban development in moderately complex terrain, such as the Plymouth met tower site, so the

calculated values from the measured data in Table 7 are somewhat higher than expected. A possible explanation for the higher than expected wind shear values is that the lower anemometers may be heavily influenced by the surrounding foliage and buildings, or the sensor heights listed in the tower documentation may not be precise, which will introduce error in the shear exponent calculation. Other sources of random or biased error may also be influencing the data, such as sensors that are not level or functioning properly.

Because of the difference between the Consultant's expectations and the calculated values, the Consultant thought it prudent to use an alternative method to estimate the wind shear based on ground cover conditions at the met tower site. The Consultant calculated an "effective ground level" at which the wind speeds are expected to be close to zero, which is estimated to be 90 percent of the surrounding tree height, or 9 m. The met tower measurement heights were reduced by 9 m and the wind shear was recalculated based on the new measurement height values. Using this method, the Consultant estimated the average wind shear at the met tower site to be 0.27. When applying this wind shear to the measured 50 m data, the monthly and diurnal pattern of the measured wind shear values was preserved, but the magnitude was adjusted from an overall average of 0.34 to 0.27. The downward adjustment results in a more conservative wind speed estimate for the met tower site.

With these assumptions, the long-term, annual average wind speed at a height of 80 m above ground level was calculated to be 6.7 m/s. This is generally consistent, but slightly lower than the value shown on the New England Wind Map. Table 8 lists the long-term estimated monthly average wind speeds at 50 m agl and 80 m agl for the met tower site.

Table 8
Estimated Long-Term Monthly Average Wind Speeds

Month	**50 m Height**	**80 m Height**
Jan	6.7	7.7
Feb	6.5	7.4
Mar	6.5	7.3
Apr	6.2	7.2
May	5.8	6.5
Jun	5.0	5.6
Jul	5.1	5.7
Aug	5.1	5.8
Sep	5.3	6.0
Oct	6.2	7.1
Nov	6.2	7.1
Dec	6.2	7.2
Ave	**5.9**	**6.7**

The estimated wind speed at 80 m is highly sensitive to the wind shear assumption. The baseline values are a best estimate of site conditions; however, there is a high level of uncertainty associated with these estimates. Table 9 shows the influence on the estimated long-term average

wind speed from varying estimates of wind shear. The range of possible values is included in the uncertainty analysis.

Table 9
Long-Term Average Wind Speeds for Several Different Wind Shear Values

Wind Shear Exponent	80 m agl Long-Term Wind Speed
0.22	6.6
0.27(1)	6.7
0.34(2)	7.0

Notes:

1. Represents the Consultant's best estimate given the information available.

2. Represents the measured vertical wind shear coefficient, which is believed to be impacted by surrounding vegetation and buildings.

Table 10 presents the annualized wind frequency distribution at various potential wind turbine hub heights above ground level.

Table 10
Annualized Wind Speed Frequency Distribution

Wind Speed Bin Center, m/s	Annualized Hours, 80 m agl	Annualized Hours, 75 m agl	Annualized Hours, 65 m agl
0.5	73	74	76
1	63	63	68
1.5	88	90	98
2	151	153	171
2.5	217	223	243
3	302	308	347
3.5	401	403	448
4	481	496	531
4.5	549	549	602
5	621	628	686
5.5	681	690	750
6	713	721	745
6.5	690	688	676
7	609	625	642
7.5	586	563	502
8	461	462	413
8.5	383	378	339
9	315	304	261

Table 10
Annualized Wind Speed Frequency Distribution

Wind Speed Bin Center, m/s	Annualized Hours, 80 m agl	Annualized Hours, 75 m agl	Annualized Hours, 65 m agl
9.5	242	234	194
10	187	184	170
10.5	160	151	130
11	117	119	110
11.5	109	107	99
12	93	91	78
12.5	74	76	77
13	77	71	58
13.5	59	60	49
14	47	45	38
14.5	42	39	36
15	33	34	23
15.5	28	26	20
16	18	19	12
16.5	18	14	9
17	9	9	10
17.5	9	10	11
18	11	11	8
18.5	7	6	6
19	7	7	5
19.5	7	5	5
20	5	5	2
20.5	3	3	4
21	3	3	2
21.5	3	4	1
22	3	2	2
22.5	2	2	1
>22.5	4	4	1

Gross Energy Estimates

The proposed turbine locations are 1.5 km southeast of the met tower location. To estimate the energy from the proposed project at the WWTP, the influence of topography on wind resource between the met tower and the turbine locations needs to be addressed. The elevation of the met tower site is the same as the proposed wind turbine locations, and the relative exposures of the sites are similar, assuming some trees will be cleared from the WWTP site to facilitate wind

turbine installation. Therefore, the Consultant concludes that the met tower data is representative of the proposed wind turbine locations and no adjustments were made to the met tower data to account for topographic or exposure variations. The New England Wind Map suggests that the average wind speed at the turbine locations may be 0.1 m/s lower than the wind speed at the met tower location. The potential impact of this discrepancy on potential energy production is included in the uncertainty analysis. The Consultant estimates that the WWTP site air density is 1.228 kilograms per cubic meter (“kg/m^3”).

The estimated hourly average wind speeds at various turbine hub heights were summarized in a frequency distribution. The gross annual energy production was calculated using the density-specific power curve from representative wind turbines and the annual average frequency distribution at that turbine hub height. The wind turbines studied are the 1.5-MW GE 1.5sle with a 77 m rotor diameter, the 1.65-MW Vestas V82 with an 82 m rotor diameter, 1.5-MW Fuhrländer FL1500 with a 77 m rotor diameter, the 1-MW Mitsubishi 1000-A with a 61 m rotor diameter, the 900-kW Americas Wind Energy AWE-900 with a 54 m rotor diameter, the 600-kW Fuhrländer FL600 with a 50 m rotor diameter, and the 600-kW Vestas RRB PS600 with a 47 m rotor diameter. Wind turbines in this size range have previously been used or proposed for community wind projects in Massachusetts, and the Consultant believes these turbine models are representative of the models that could be procured for the WWTP site. The GE 1.5sle wind turbine was specified by MTC to be used as the basis for this study, and the majority of the analysis focuses on that wind turbine. There are several other wind turbine models currently available that may also be suitable for the WWTP site. The Consultant expects the results of this analysis to be representative of the range of results that would be obtained if other similar wind turbines were analyzed. However, a detailed analysis of candidate wind turbines should be conducted before detailed project design and equipment procurement activities commence. In addition, the turbine manufacturer must be consulted to determine site suitability.

Power production from a wind turbine is a function of wind speed. The relationship between wind speed and power is defined by a power curve, which is unique to each turbine model and, in some cases, unique to site-specific settings such as turbulence and air density. The sea-level power curves from representative wind turbines are provided as Table A-1 in Appendix A of this Report.

Table 11 summarizes the gross energy production estimates from each wind turbine type on a per turbine basis. In each case, the wind frequency distribution was adjusted to the specified turbine hub height. Although Table 11 provides estimated energy production from a single wind turbine, the proposed wind turbine layout includes up to two wind turbine locations, as will be discussed in a following section.

Table 11
Estimated Gross Annual Energy Output on a per Turbine Basis

Turbine Model	GE 1.5sle	V82	FL1500	MWT 1000-A	AWE 900	FL600	PS600
Rotor Diameter (m)	77	82	77	61	54	50	47
Hub Height (m)	80	80	80	65	75	75	65
Rated Power (MW)	1.5	1.65	1.5	1.0	0.9	0.6	0.6
Gross Annual Output (MWh)	4,053	4,587	3,991	2,164	2,088	1,579	1,279

Table 11
Estimated Gross Annual Energy Output on a per Turbine Basis

Turbine Model	GE 1.5sle	V82	FL1500	MWT 1000-A	AWE 900	FL600	PS600
Gross Annual Capacity Factor	31%	32%	30%	25%	26%	30%	24%

As discussed in Section 4 of this Report, the FAA may impose a height restriction on this project, which would result in a maximum turbine hub height of 65 m. The resulting gross energy output of the GE 1.5sle wind turbine would be approximately 12 percent lower than the 80 m hub height option, resulting in an estimated gross capacity factor of 27 percent.

Expected Energy Losses

The gross annual energy presented above represents the energy delivered at the base of the tower under ideal conditions. Net annual energy production takes into account typical losses and represents the energy delivered to the grid interconnection point for a typical (average) year. For the WWTP site, the Consultant estimated energy losses from a variety of sources. Exact losses can vary significantly from project to project; for example, some projects with poor transmission access may experience significant line outages or curtailment. For the purpose of this assessment, the Consultant assumed typical values for parameters where site-specific information was not available at this time. The following items provide an overview of the sources of losses. For the purpose of uncertainty modeling, the following losses are normally distributed with uncertainty values listed at one standard deviation, unless otherwise noted.

Routine Maintenance Downtime: This item includes energy lost during periods of routine maintenance of the wind turbines. Time spent for maintenance of typical modern megawatt-scale wind turbines is approximately 40 hours to 120 hours per year. The magnitude can vary depending on turbine complexity, cleaning requirements, and frequency of larger tasks such as gear oil changes. The Consultant estimated routine maintenance downtime of 60 hours per year (or 0.7 percent of the year). The relationship between time spent on routine maintenance and energy loss was also modeled as an uncertainty, with a best estimate of a multiplier of 0.6 of energy per unit time and an uncertainty of 0.1 around this estimate. Consequently, the P50 case represents an energy loss of approximately 0.4 percent. [The P50 value represents the average expected value, or the value below which 50 percent of the outcomes are expected to be found.]

Fault Downtime: Some downtime will be incurred associated with turbine faults. The P50-case fault downtime values estimated by the Consultant were approximately 1.5 percent for Year 1 and approximately 1.1 percent (or 100 hours per year) thereafter. This estimate assumes that the wind turbines will be monitored remotely and that faults will be reset in a timely manner. Based on the Consultant's experience with other projects using pitch-regulated turbines, fault downtime is heavily weighted towards high-wind periods. Consequently, the relationship between faults and energy loss was also modeled as an uncertainty, with a best estimate of a multiplier of 1.7 of energy per unit time and an uncertainty of 0.2 around this estimate. The Consultant estimated the resulting P50 average energy loss as approximately 2.0 percent.

Minor Component Failure Downtime: Some downtime will be incurred associated with failures of smaller components such as motors, relays, valves, power electronics, sensors, controllers, and bushings; and other small malfunctions normally experienced by modern

megawatt-scale wind turbines. As the equipment ages, failure of minor components with design lives less than 20 years is expected to increase.

Based on experience, the Consultant estimated the minor component failure downtime values to be 1 percent over Years 1-5, 2.2 percent over Years 6-10, 2.8 percent over Years 11-15, and 3.2 percent thereafter. The majority of the components evaluated are expected to have mean lives of approximately 10 years, so the replacement rate tends to level off later in the project life. The Consultant's expectation based on experience with operating wind projects is that component failures will be slightly weighted towards high-wind periods; consequently, the relationship between minor component failures and energy loss was also modeled as an uncertainty, with a best estimate of a multiplier of 1.2 of energy per unit time and an uncertainty of 0.1 around this estimate. The Consultant estimated the resulting P50 average energy loss as approximately 2.8 percent.

Major Component Failure: Some downtime will be associated with major systems in the turbines. Examples of such events include gearbox, generator, or blade replacements, yaw system failures, or similar problems. These issues may cause the wind turbines to be off line for an extended period of time. While a typical year may have relatively limited downtime associated with major failures relative to the project life average, the infrequent events can result in significant lost energy. These losses are also expected to increase over time, as turbine systems wear out and more gearboxes and other components fail. The Consultant estimates that the frequency of failure of major components is expected to begin increasing in Years 6-10 of the turbine's life and continue to increase for the remainder of the turbine design life.

The P50-case major component failure downtime values estimated by the Consultant were 1 percent for Years 1-5, 2 percent for Years 6-0, 3 percent for Years 11-15, and 4 percent for Years 16-20. The losses associated with major failures were modeled as an asymmetrical distribution with a long tail, representing small possibilities of significant downtime; however, the majority of losses are expected to be at or less than the mean. The Consultant's expectation based on experience with operating wind projects is that component failures will be slightly weighted towards high-wind periods. Consequently, the relationship between major component failures and energy loss was also modeled as an uncertainty, with a best estimate of a multiplier of 1.2 of energy per unit time and an uncertainty of 0.1 around this estimate. The Consultant estimated the resulting P50 average energy loss as approximately 3 percent.

Balance-of-Plant Downtime: Approximately 10 to 20 hours of downtime are associated with annual maintenance on project infrastructure (such as the project substation, pad mount transformers, etc.). These activities are typically planned events that coincide with low-wind months and days. Unplanned failures and repairs associated with a wind energy plant's balance-of-plant systems and equipment ("BOP"), such as substation transformer failures, electrical collection system or communication system problems, or transmission outages are uncommon; however, their impact on lost production could be considerable. The mean loss related to both planned and unplanned BOP events has been estimated to be 0.5 percent and is not expected to increase over time. The losses associated with BOP failures were modeled as an asymmetrical distribution with a long tail, representing small possibilities of significant downtime; however, the majority of losses are expected to be at or less than the mean.

Turbine Wake: As will be discussed in a later section, the proposed site layout includes up to two wind turbine locations. The Consultant modeled wake losses using the two-turbine site

layout and the WindFarm software package to estimate the losses for each turbine. The P50 estimated wake loss was calculated at 4 percent. If a single wind turbine is installed instead of two, wake losses would be 0 percent.

Electric Line: Electric line losses are primarily a function of efficiency of the transformers used at the facility, sizing of the electric cabling comprising the on-site collection and distribution system, and parasitic consumption in very low wind conditions. The Consultant assumed a mean electric loss of 1.5 percent, which generally reasonable considering the proposed electric system. A standard deviation of 0.5 percent was assumed and possible losses ranged between 0.5 percent and 2.5 percent.

Turbulence/Control System: Turbulence and control system losses include a variety of issues related to the normal control of the wind turbine that prevent performance in accordance with the reference power curve. These issues include high-wind hysteresis (production lost during the time it takes to recover from automatic high-wind shutdowns), low-wind hysteresis (startup and cut-in), off-yaw operations, and cable untwists. The Consultant estimated 1 percent losses for these issues, with a range from 0 percent to 2 percent.

Blade Soiling: This item, which includes accumulation of dirt and insects on blades, can impact energy production. These losses will be site-dependent; the Consultant estimated 0.5 percent since the WWTP site is not particularly dry or dusty and because the primary wind turbine under consideration is pitch-regulated and is affected less from these issues than stall-regulated wind turbines.

Blade Degradation: Typically, turbine performance decreases somewhat over the life of a project. Degradation of the blade surface is the largest factor that can produce such a change. The turbine blade performance will gradually degrade over time. A small annual decrease in performance was included in the model, with a most likely case loss averaging approximately 0.4 percent over 20 years (beginning with zero losses and slowly increasing following an exponential decay curve to 1 percent by Year 20).

Icing/Weather: The types and magnitudes of weather-related losses will vary by project, but may include icing, high or low ambient temperature cutouts, reduced site access due to inclement weather, and shutdowns to avoid hail, lightning, or other storm damage. The Consultant's experience with operating projects in similar climates indicates that the weather-related losses are highly variable from site to site, and from year to year. For example, the frequency and duration of icing events can vary substantially, with most years having little ice while others experience events where sites are frozen for days at a time with little or no turbine production. Similarly, lightning damage to turbines occurs in infrequent, intermittent events, but can produce significant periods of downtime.

Based on a review of the meteorological data, the Consultant estimated a typical case loss of 2.0 percent for weather conditions, with a range of potential weather losses from 0.5 percent to 4.5 percent. This results in a P50 loss of 2.3 percent. It should be noted that this value represents energy loss and not percentage of time lost, as weather downtime frequently occurs during higher-than-average wind conditions.

Power Performance: Turbines may perform at a level different from the reference power curve for reasons other than those counted in other losses, such as blade soiling and degradation, turbulence, etc. This is modeled as a distribution of possible outcomes with a most likely value

of 0 percent, a small potential for up to 3 percent higher performance and a small potential for 5 percent lower performance. The P50 case is equivalent to a 0.25 percent reduction in power averaged over the life of the project.

Effect of Asymmetric Uncertainties: Some of the loss factors described earlier are asymmetric (or lopsided) in nature. To the extent loss factors are asymmetric, the effect of the asymmetry is captured in the spread of the P1-P99 energy estimate values as well as the P50 loss values. Although the uncertainties described below are symmetric, their effect on energy is asymmetric because of the non-linear relationship of wind speed to energy. That is, small increases in average winds result in proportionally smaller changes in energy compared to small decreases in average winds. The effect of this asymmetric energy uncertainty distribution is small compared to other losses, but it does result in a small energy loss factor that is included as the "effect of asymmetric uncertainties." Table 12 summarizes the values estimated for each energy loss category.

Table 12
Summary of P50 Long-Term Average Losses

Loss Category	Losses, Percent of Energy
Routine maintenance	0.4
Faults	2.0
Minor components (1)	2.8
Major components (1)	3.0
Balance of plant	0.5
Wake	4.0
Electrical line	1.5
Blade soiling	0.5
Weather, including icing, lightning, hail	2.3
Turbulence and controls	1.0
Blade degradation (1)	0.4
Power performance	0.2
Effect of asymmetric uncertainties	0.3
Total	**17.5 percent**

Notes:
1. *Values are long-term averages over a 20-year project life and are lower in initial years of operation.*

Uncertainties

This section describes the various sources of uncertainty in the energy analysis for the proposed project given the aforementioned assumptions and considerations. The uncertainties are typically estimated as percentages of the mean wind speed for a site. Based on the wind

frequency distribution for the project and the GE 1.5sle wind turbine power curve, there is an approximate relationship of an uncertainty of 2.2 percent on energy for each 1 percent uncertainty on wind speed. This relationship varies with speed because the power curve flattens at high wind speeds; there is a smaller increase in energy when wind speeds increase relative to the magnitude of the decrease in energy as wind speeds decrease. After converting all uncertainties to percentages of energy, the uncertainties were added as the square root of the sum of the square of each value. Except as noted below, all uncertainties on wind speed shown are assumed to be normally distributed; uncertainty values listed are at one standard deviation.

- **Anemometer Accuracy**: This parameter represents the variability in measurement of wind by individual anemometers. An uncertainty of approximately 2 percent on wind speed was estimated based on the typical error on measurements found in testing of a large number of NRG Maximum #40 anemometers similar to those used as the primary anemometer at the Plymouth met tower site.
- **Tower Effects/Measurement Biases**: Some uncertainty is associated with the mounting effects of anemometers on towers; even when mounted according to industry-standard procedures, small speed-up and slow-down effects are seen on measurements on tubular tilt-up towers. At the Plymouth met tower site, pairs of anemometers are present at the 50-m and 38-m levels, allowing for selection of unwaked wind speeds and minimization of measurement effects. Based on the site visit to the met tower, a review of the documentation of the mounting arrangements on the towers and a review of the data, the Consultant estimated an overall site-wide average wind speed uncertainty of 1 percent for this issue.
- **Data Capture/Recovery, Quality Control/Validation Procedures**: This uncertainty covers issues related to missing, invalid, or questionable data. Several periods of data were removed from the met tower data set for a variety of reasons, including icing, missing data, and failed tower components. The Consultant estimated an uncertainty of 1.5 percent on wind speed for this issue.
- **Representativeness of Period of Record:** Data from a single long-term meteorological stations were investigated to determine the interannual wind conditions for the region. The interannual variability was calculated at approximately 4 percent of the mean. This degree of variability is consistent with the expected wind variability in the region. There is an 11-year period of record at the reference site that was used in this analysis. Based on these values, the uncertainty associated with the representativeness of the period of record equals 4 percent divided by the square root of 11, or 1.2 percent on wind speed.
- **Reference Site Relationships/ Consistency of Long-Term References**: This topic represents the uncertainty on the relationship to the long-term reference station used to adjust the observed site wind speeds to long-term conditions, and also on the consistency of the long-term data sets used to describe the wind conditions between tower locations. The Consultant expects the uncertainty on the relationship to be low based on the strong correlation to site wind speeds and the long period of data available as a long-term reference. The Consultant estimated the combined uncertainty for these issues at 1 percent.
- **Wind Shear Estimates**: There is some uncertainty on whether the shears measured over the period at the tower locations are representative of the long term. Shear can also vary based on the exposure at a met tower relative to turbine locations, seasonal variation, vegetation or seasonal changes in vegetation, and other effects. The Consultant estimated the overall shear

uncertainty based on a combination of these issues. The effective aggregate uncertainty associated with shear was estimated at approximately 4 percent on wind speed, due to the difference between the measured shear and the Consultant's expectations of reasonable shear values based on other sites in similar terrain.

- **Topographic Effects**: This uncertainty represents the potential difference in wind speed between the met tower location and the wind turbine locations. The site consists of moderately complex terrain with the met tower situated in a location representative of the proposed turbine locations. Based on a review of topographic maps and information from the site visit, the Consultant would expect little variation in wind speeds between the met tower and wind turbine locations; therefore, the Consultant estimated the uncertainty on wind speed at 1.5 percent.
- **Wind Frequency Distribution**: The uncertainty on the wind frequency distribution represents the possibility that for a given wind speed the energy production may be higher or lower than expected due to a more or less favorable distribution of winds. For example, the frequency of high-wind cutouts; a year with several intense storms may record substantial time at wind speeds above the 25 m/s turbine cutout speed, thereby increasing the overall average wind speed but not increasing the energy production. There are two aspects to this uncertainty: the first represents the uncertainty on the distribution measured over the period of measurement at the Plymouth met tower site and the second represents the year-to-year variability in the wind speed distribution. The Consultant estimated an annual variability of 3 percent on energy related to differences in wind distribution.
- **Turbine Wake Loss Model**: There are two sources of uncertainty on the wake loss estimate: uncertainty on the accuracy of the wake loss model, and uncertainty on the model input. The Consultant estimated the uncertainty on the model accuracy by evaluating results predicted by different combinations of wake loss models and wake combination methods available within the WindFarm software package; these included axisymmetric wake and WAsP/Park wake velocity deficit models, and sum of squares of wakes and energy balance combination methods. The average of these results was used as the base case, with the highest of the four models predicting a 3.3 percent loss and the lowest predicting a 3.1 percent loss. The average of the model outcomes is a reasonable approximation of wake losses on most projects. In addition to uncertainty associated with the loss model, the Consultant estimated a 1.0 percent uncertainty on the model inputs, including turbulence at hub height and wind direction distribution. Based on the results of the various tests of model combinations and consideration of these other issues, the Consultant estimated a combined wake loss uncertainty of 1.1 percent of energy.
- **Wind Speeds over Project Life Relative to Long-Term Average**: Uncertainty exists regarding whether the true long-term mean wind speed will occur over the project life. Given an assumed 20-year project lifespan and a 4 percent interannual variability, this uncertainty is calculated as 4 percent divided by the square root of 20 or 0.9 percent on wind speed. For the 1-year energy analysis, this parameter was set to 4 percent on wind speed.
- **Changes in Long-Term Average Wind Speed**: Changes to local or global climate patterns may produce changes in site wind conditions over the life of the project; there is uncertainty as to whether such changes are occurring, and if so, to what extent. The Consultant assumed a 1.0 percent uncertainty on wind speed to account for this issue.

Table 13 summarizes the uncertainty on wind speed and energy for each component and the root-sum-square of each component.

Table 13
Summary of Uncertainty Estimates

Uncertainty Type	GE 1.5sle wind turbine	
	Uncertainty on Wind Speed	**Uncertainty on Energy**
Anemometer Accuracy	2.0%	4.4%
Tower Effects on Measurements	1.0%	2.2%
Data Reduction Procedure Accuracy	1.5%	3.3%
Representativeness of Period of Record	1.2%	2.6%
Long-Term Correlation	1.0%	2.2%
Wind Shear Uncertainty	4.0%	8.8%
Topographic Affects	1.5%	3.3%
Frequency Distribution	N/A	3%
Wake	N/A	1%
Wind Speeds During Project Life Relative to Long-term Average	0.9%	1.98%
Changes in Long-term Average	1.0%	2.2%
Root-Sum-Square	**5.5%**	**12.4%**

Net Energy Estimates

The net energy production estimates at a range of confidence levels are evaluated using a stochastic model to evaluate the uncertainty in the assumptions, methods, and losses used for the analysis. Distributions appropriate for each were determined and a probabilistic description of the annual net energy was built integrating each source. The model was then run in 10,000 iterations with each parameter changed randomly and independently to describe the distribution of net energy estimates. These results were then summarized to determine the probability of exceedance at various levels of confidence.

Table 14 presents the resulting net energy estimates and capacity factors for two 80-meter hub height GE 1.5sle wind turbine located on the proposed WWTP site at a range of probability-of-exceedance levels. For example, there is a 75 percent probability that the energy production from the project will exceed 6,140 MWh/yr and a 25 percent probability the energy production will be less.

Table 14
20-Year Average Net Annual Energy Estimates,
Two GE 1.5sle Wind Turbines, 65 m Hub Height

Probability of Exceedance	Net Energy, MWh/yr	Net Capacity Factor
1%	7,945	30.2%

Table 14
20-Year Average Net Annual Energy Estimates,
Two GE 1.5sle Wind Turbines, 65 m Hub Height

Probability of Exceedance	Net Energy, MWh/yr	Net Capacity Factor
5%	7,147	27.2%
10%	6,859	26.1%
25%	6,384	24.3%
50%	5,884	22.4%
75%	5,386	20.5%
90%	4,982	19.0%
95%	4,733	18.0%
99%	4,493	17.1%

Table 15 presents the resulting net energy estimates and capacity factors for one 65-meter hub height GE 1.5sle wind turbine located on the proposed WWTP site at a range of probability-of-exceedance levels.

Table 15
20-Year Average Net Annual Energy Estimates,
One GE 1.5sle Wind Turbine, 65 m Hub Height

Probability of Exceedance	Net Energy, MWh/yr	Net Capacity Factor
1%	4,010	30.5%
5%	3,718	28.3%
10%	3,580	27.2%
25%	3,326	25.3%
50%	3,058	23.3%
75%	2,806	21.4%
90%	2,592	19.7%
95%	2,472	18.8%
99%	2,248	17.1%

Note:
Does not include turbine-to-turbine wake losses since this table presents results for a single turbine installation only.

Estimated net power production on a 12-month by 24-hour basis for two GE 1.5sle wind turbines is presented in Table 16; such a 12x24 matrix provides information regarding the expected

seasonal and diurnal variation in power output. The estimates include expected energy losses described above. Note that this matrix is an estimate of the pattern of average power production. The actual power production in any given hour or month may deviate significantly from this pattern. In addition, the uncertainty for a given hour of a given month is much larger than the uncertainty on the annual energy production.

Table 16
Estimated 12-Month by 24-Hour Net Power Production for Two GE 1.5sle Turbines with 77-m Rotor Diameter and 80-m Hub Height at WWTP Site, kW

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
0	939	932	875	994	973	453	523	616	527	919	958	906	799
1	948	888	934	934	932	560	539	653	525	950	989	955	817
2	971	1,008	944	923	940	590	504	597	584	1029	950	994	834
3	1,024	926	946	811	946	542	497	538	511	954	951	1,081	808
4	931	936	957	821	948	491	524	549	504	935	911	1,081	796
5	853	887	940	817	868	446	505	498	500	988	978	1,027	775
6	912	905	974	739	747	411	367	366	554	1,016	908	1,093	749
7	1,010	829	1,014	781	640	314	342	316	455	873	902	1,053	714
8	1,094	845	927	713	602	339	346	393	573	821	943	1,002	720
9	999	812	975	798	599	362	390	479	613	797	919	929	726
10	1,066	883	932	835	546	383	429	477	503	773	957	829	724
11	1,111	919	962	868	532	432	534	485	537	716	935	830	745
12	1,106	993	956	911	492	434	548	554	530	688	872	811	749
13	1,114	993	976	1,048	488	453	625	583	609	687	908	814	782
14	1,069	1,086	958	1,034	555	490	683	682	688	799	814	750	806
15	974	989	891	1,081	554	519	643	631	652	782	774	681	769
16	854	941	972	1,024	583	466	672	590	588	769	656	607	731
17	778	900	945	1,006	619	435	568	509	544	828	665	640	706
18	822	847	818	906	651	435	493	517	550	918	756	862	717
19	854	812	832	906	794	475	458	543	660	973	709	835	736
20	999	970	855	1,007	783	444	601	609	723	945	679	822	785
21	964	972	875	990	811	441	616	634	646	967	782	894	799
22	971	901	888	969	818	430	606	679	614	971	885	959	808
23	988	982	921	933	843	477	545	604	594	888	881	887	794
Ave	**973**	**923**	**928**	**910**	**719**	**451**	**523**	**546**	**574**	**874**	**861**	**887**	**766**

For comparison purposes, the net annual energy estimates for other types of wind turbines are presented in Table 17, based on a 50 percent probability-of-exceedance level. For the GE 1.5sle net annual energy estimates are presented for both an 80-m hub height and a 65-m hub height.

Table 17
20-Year Average Net Annual Energy Estimates, Single Turbine,
50 percent Probability of Exceedance

Turbine Model	Hub Height, m	Quantity	Net Energy, MWh/yr	Net Capacity Factor
GE 1.5sle/77	80	1	3,486	27%
GE 1.5sle/77	65	1	3,060	22%
V82	80	1	3,945	28%
FL1500	80	1	3,432	26%
MWT1000A	65	1	1,861	22%
AWE900	65	1	1,796	22%
FL600	75	1	1,358	26%
PS600	75	1	1,100	21%

As can be seen in Table 17, wake loss modeling for each wind turbine model to determine net energy estimates is not provided for a two-turbine installation option, only for a single-turbine installation. In contrast, referring back to Table 14, the wake losses for two GE 1.5sle turbines result in a lower net capacity factor and a lower annual net energy generation per turbine.

Section 4
CONCEPTUAL DESIGN

Site Physical Characteristics

The Consultant's objective was to assess the WWTP site's physical characteristics, including topography, land cover, land use, access roads, and buildings; to evaluate the suitability of potential wind turbine locations from an operational viewpoint; to describe required and recommended spatial separation of the wind turbine from buildings and pedestrian or vehicular traffic; to evaluate the ability to deliver wind turbine components and installation equipment to the site (via land or air); and to identify necessary access road modifications required for each potential wind turbine location.

Based on detailed maps and other information provided by Plymouth and observations made during site visits, the Consultant evaluated the WWTP site to determine its suitability for utility-scale wind energy project development. Following is a summary of the investigation including recommendations of topics Plymouth should consider to move forward with the development of a utility-scale wind power project.

Obstructions to the Wind Resource

On-site measured wind speed and direction data from May 2007 through April 2008 indicate the prevailing wind direction, from both time duration and an energy-content basis, are generally from the southwest (see the wind resource section for more detail). Besides the trees noted previously, there are currently no significant upwind obstructions to the wind resource at either the met tower location or potential wind turbine locations that would need to be taken into account in this analysis. Future development of utility-scale wind turbines or other tall structures within 1,000 m upwind of the WWTP may impact the airflow at the WWTP and would need to be evaluated further.

Required Setbacks and Height Restrictions

Airspace Evaluation

MTC contracted Aviations Systems, Inc. to perform an airspace obstruction evaluation regarding Plymouth (the "Airspace Evaluation"), which is attached as Appendix B. The Airspace Evaluation was specific to a potential turbine location with coordinates generally at the WWTP site using an elevation of 144 feet (43.9 m) above mean sea level ("amsl") and a turbine height of 397 feet (121 m) agl. The Airspace Evaluation concluded that the nearest public or military air facility is the Plymouth Municipal Airport, which is approximately 3.82 nautical miles (7.1 km) from the WWTP site and that the WWTP site is approximately 27.03 nautical miles (50.1 km) from the federal government's Boston/North Truro Joint Use Long Range Radar facility and that – subject to current policy of the National Air Defense and the Department of Homeland Security – any proposed wind turbine may be required to undergo an individual assessment by FAA. The Airspace Evaluation further concludes that any wind turbine from 316 feet 96.3 m) agl to 354 feet (107.9 m) agl "…should be approvable but require extended study". Refer to Appendix B for further detail.

Additionally, the U. S. Department of Defense, Missile Defense Agency ("USDOD") operates an early warning radar system at the Cape Cod Air Force Station, which is identified as the PAVE Phased-Array Warning System ("PAWS"). The PAVE PAWS is used primarily to detect and track sea-launched ballistic missiles and inter-continental ballistic missiles and secondarily to track and detect Earth-orbiting satellites. A land-based wind turbine could potentially interfere with the PAVE PAWS if the turbine is located within the PAVE PAWS coverage area and depending on the turbine's height and proximity to the PAVE PAWS installation. The PAVE PAWS coverage area is depicted in Appendix C; and, as can be seen in Figure 2 of Appendix C, while portions of Plymouth are within the PAVE PAWS coverage area, the WWTP site is not.

Wind Bylaw

Plymouth has enacted Plymouth Code, Chapter 205, Section 205-73 titled "Wind Energy Facilities" (the "Wind Bylaw"), which is designed to encourage by special permit the development and use of wind energy. Under the Wind Bylaw a wind facility may be erected by special permit on land that contains a minimum of five acres subject to certain conditions. Wind turbine setback required by the Wind Bylaw must be no less than turbine maximum tip height plus 50 feet (15.2 m) and never less than 100 feet (30.5 m) from any lot line. Wind turbines are limited to a maximum height of 350 feet (106.7 m) from to the top of the hub where the rotors attach. Under the Wind Bylaw, noise from a wind turbine is specified not to exceed a sound power level at grade level of 60 decibels on an A-weighted basis ("dBA") at any property line. The Wind Bylaw contains other provisions, including among other things, a surety for removal costs at the end of a wind turbine's use.

The setbacks required by the Wind Bylaw are consistent with ranges of setbacks used in similar wind turbine projects with which the Consultant is familiar. For example, the Model Amendment to a Zoning Ordinance or By-Law prepared by the Massachusetts Division of Energy Resources includes a setback distance equal to 1.5 times the maximum tip height ("MTH") of the wind turbine blades from the nearest existing residential or commercial structure. This is generally referred to as a safety setback, and the area within this setback should be clear of occupied buildings, roads, or other areas normally occupied by the public and on-site personnel.

Table 18 identifies the MTH and 1.5 times MTH for different wind turbine models. The height limit in the Wind Bylaw is defined by the hub height of the wind turbine as opposed to the MTH, which is more commonly used. Each of the turbine types presented in Table 18 satisfy the Wind Bylaw hub height limit of 106.7 m. The FAA may have additional, more restrictive height restrictions. As previously discussed, the Airspace Evaluation concludes that a wind turbine with a MTH of up to 108 m above ground level should be approvable but require extended analysis. This potential height restriction would require that the GE, Vestas, and Fuhrländer FL1500 turbine options be installed on a 65 m tower instead of an 80 m tower as shown in Table 18, except for the GE 1.5sle which is indicated with both hub heights in Table 18. A final determination from the FAA has not yet been requested; therefore, an 80 m turbine hub height is assumed in this analysis for the GE1.5sle turbine.

Table 18
Dimensions of Potential Wind Turbine Models

Turbine Model	Rated Capacity, kW	Rotor Diameter, m	Hub Height, m	MTH, m	1.5 x MTH, m
GE 1.5sle	1,500	77	80	118.5	178
GE 1.5sle	1,500	77	65	103.5	155
Vestas V82	1,650	82	80	121	182
Fuhrländer FL1500/77	1,500	77	80	118.5	178
Mitsubishi MWT-1000A	1,000	61	65	92	138
Vestas RRB PS600	600	47	65	88.5	133
Fuhrländer FL600	600	50	75	100	150
Americas Wind Energy AWE-900	900	54	75	101	152

In addition to the noise setback requirement in the Wind Bylaw, the Massachusetts Department of Environmental Protection ("MDEP") has a policy requiring that commercial developments not increase background noise levels more than 10 dB measured at a property boundary. Based on a preliminary analysis of sound pressure levels generated by a 1.5 MW wind turbine with an 80 m hub height, a distance of 1.5 times MTH is sufficient in satisfying both the Wind Bylaw and MDEP's noise policy assuming that the background noise level at the WWTP site is 43 dBA or greater. At this distance the perceived wind turbine noise levels are low enough to be masked by background noise. Accordingly, when identifying potential wind turbine locations, the Consultant uses a noise setback of 1.5 times MTH, recognizing that such a setback will likely satisfy the noise limitation of the Wind Bylaw depending on the determined background noise level of the site.

Wind Turbine Locations

Because of the southwest-to-northeast orientation of the available land at the WWTP site, there are limited well-exposed areas that offer turbine locations perpendicular to the prevailing southwest wind direction. Based on the Consultant's review of the elevation map of the property, the highest elevation at the WWTP site, and subsequently the area of greatest wind exposure, is located along the southeastern half of the property. The ground elevation in this area is approximately 44 m above mean sea level. The northwestern half of the property is a lower elevation and is occupied by the WWTP and was therefore eliminated from consideration of wind turbine placement.

Based on the setback requirements discussed above, the Consultant estimate that the southeastern portion of the WWTP property is capable of supporting two 1.5 MW class wind turbines with a rotor diameter of approximately 77 m and a hub height of 80 m. Figure 10 depicts the two potential wind turbine locations based on the GE 1.5sle with a tower height of 80 m (maximum tip height of 118.5 m) and a rotor diameter of 77 m. The locations represent what the Consultant expects to be the highest wind resource and lowest construction cost locations that are suitable for wind turbine installation on the property. The proposed locations take into account the prevailing wind direction, elevation, access to roads, and the setbacks as described above.

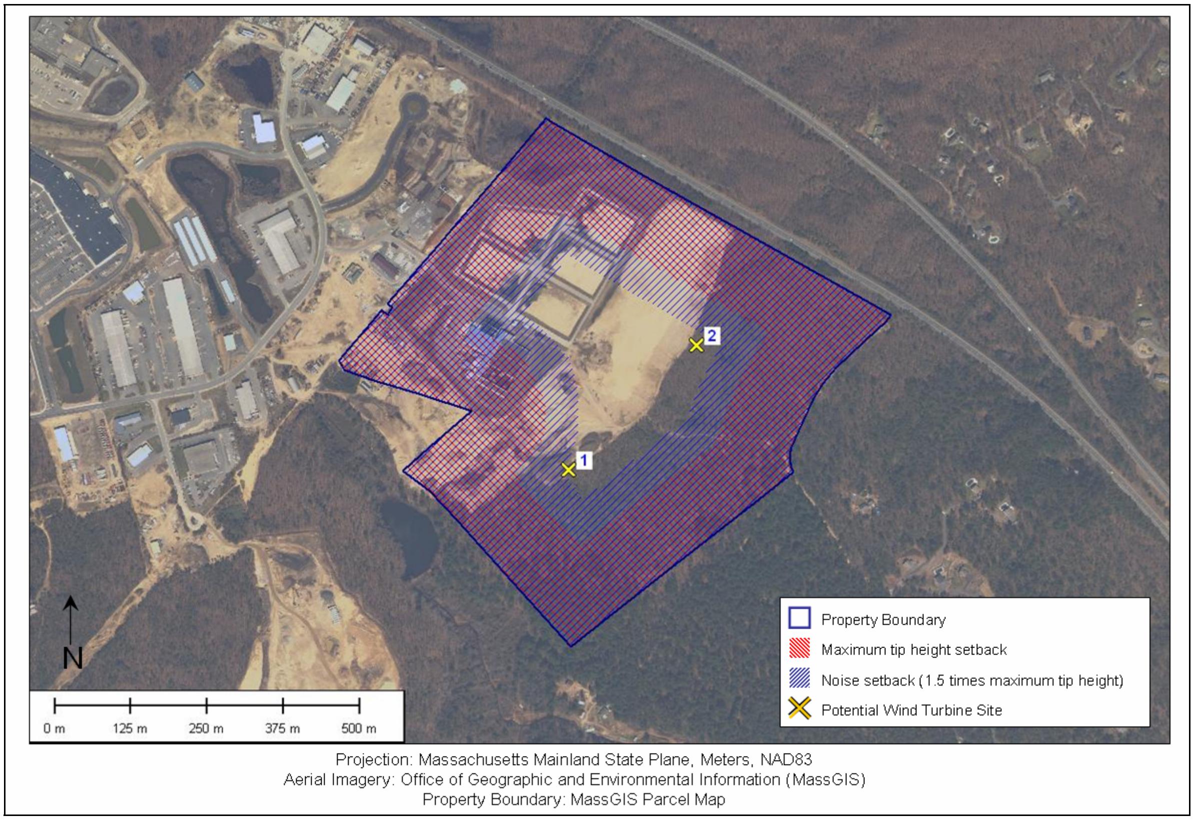


Figure 10 - Two-Turbine Layout, GE 1.5sle with MTH of 178 m

Although it is estimated that two 1.5 MW turbines can physically be placed on the WWTP property, the installation of a single 1.5 MW turbine or two smaller, sub-megawatt-size turbines may be more appropriate for the site conditions. The potential wind turbine locations shown in Figure 10 are spaced 3.5 rotor diameters apart, assuming a wind turbine with a rotor diameter of 77 m, whereas industry best practices typically result in a downwind spacing of at least 8 to 10 rotor diameters. This relatively close spacing in the downwind direction may result in higher than normal turbulence on the downwind turbine, which may cause accelerated fatigue and higher maintenance requirements. The adequacy of this spacing also depends on other characteristics of the wind regime, such as ambient turbulence intensity, shear and the wind speed distribution. The turbine manufacturer will ultimately need to be consulted to verify site suitability. It is possible that the project may need to be reduced to one turbine if the operating conditions under the prevailing southwest winds at Site 2 in Figure 9 are found to be unacceptable by the turbine manufacturer because of the rotor wake effects from the turbine at Site 1. Alternatively, different wind turbines with smaller rotor diameters would allow for greater turbine-to-turbine spacing, which would result in lower wake effects and may be more appropriate from a site suitability perspective. In addition, a shorter tower (hub height) and resulting lower MTH may allow for the turbine locations to be placed closer to the property boundaries, thus allow increased turbine-to-turbine spacing and lowering the wake effects. However, any of these alternatives to the two 1.5-MW turbine layout would result in a reduction in expected energy production from the wind project.

Transportation Considerations

Highway access to Plymouth is relatively convenient. Plymouth is reached directly from Massachusetts Route 3. From Route 3, transportation would be along local surface roads to the WWTP site consisting of a combination of four-lane and two-lane roads. There are several significant horizontal curves along the potential transportation route; however, none appear to be problematic in transporting wind turbine components to the WWTP site.

Rail access to Plymouth also appears available; but, it is unclear at this time if rail access can be utilized for the purpose of transporting wind turbine components. A Massachusetts Bay Transit Authority rail line runs to Plymouth; however, it is used principally for commuter transportation and not for transportation of industrial items.

Alternatively, transportation via the ocean may be available given the significant number of ports in Plymouth. Unfortunately, many of the ports are serviced by smaller local roads.

Regardless, the Consultant does not expect transportation via the ocean to be an economical option since Plymouth landings cannot accept container ships. Also, road transport would have to be arranged from a landing (most likely Delaware) to the WWTP site which would require the same trucks necessary to travel between the port and the WWTP site. These trucks would probably come from out of state, so surface travel costs would be the same as if the wind turbine components were picked up at a major port. These same arguments would apply to rail transport as well.

Civil and Site Modifications

Site Development

For the WWTP site, development activities will consist of upgrades to existing access roadways, construction of new access roads, and clearing and leveling of the proposed turbine sites. An access road approximately 950 m long will be required from Camelot Drive to the two proposed wind turbine sites via the existing WWTP access roadways. Construction of each wind turbine site will require that a circular area approximately 80 m in diameter, or approximately 0.49 hectare ("ha"), be cleared and leveled. Where the existing tree line is within this limit, the felling of trees will be required. As the two wind turbine sites are relatively close together, the Consultant anticipates that the erector will "walk" the cranes between the two sites. Thus, the Consultant expects that the cleared area associated with the access roadway will be of sufficient width to allow construction of a 7.5-m wide crane path and the installation of erosion control measures during the construction period. Ultimately, once the wind turbines have been erected, the Consultant anticipates that the portions of the roadways used as a crane path will be decompacted at the end of construction such that the final access roadway width will be 5 m wide.

Subsurface Considerations

Though the Consultant did not conduct a geotechnical or soils analysis, the Consultant did not observe any conditions that would suggest that a wind energy facility as described in this Report could not be built on the WWTP site. Based on the Consultant's observations of the adjacent sand pit, and the historical geotechnical reports prepared for the construction of the WWTP, it appears that the soils that underlie the potential wind turbine sites are comprised mainly of non-

cohesive sandy soils. The Consultant therefore does not consider the existing ground conditions to pose a unique challenge to wind turbine project construction.

Construction Routing

The following discussion is in the context of accessing the proposed wind turbine locations directly from Camelot Drive using as much of the existing WWTP roadways – paved and unpaved – as possible so as to minimize land impact.

As indicated above, the required length of haul route/access roadway from Camelot Drive to the two wind turbine sites is approximately 950 m of which the first 460 m of roadway would consist of the existing paved WWTP access roadways and paved areas that surround the facility and approximately 490 m of which would be new access roadway. Approximately 305 m of the new access roadway would be between the two turbine sites and the balance would interconnect this new section to the existing paved areas. A portion of the haul route follow the existing, unpaved access ramp that climbs from the rear of the WWTP facility to an unpaved roadway that allows access to the WWTP's monitoring wells (located within the forested area above the sand pit). At the time of the Consultant's site visit, this access ramp and existing roadway consisted of a compacted sand base.

In order to meet the turning radius requirements for the wind turbine hauling equipment, a new access roadway will be required. From the top of the existing access ramp, the Consultant expects a T-type intersection will be constructed which will allow construction of a single access road between the two wind turbine locations.

Although detailed topographic information was not available, based on the Consultant's observations at the WWTP site, the Consultant generally does not believe that significant cuts or fills will be required to meet the curve radius and roadway grade requirements for the haul equipment that are specified by the wind turbine manufacturer. However, as the existing access ramp appeared to be on the order of 4-5 m wide, some removal of existing sand materials will likely be required to allow access to the wind turbine sites.

In general the on site access roads that will be constructed to allow the delivery and erection of the wind turbines will have a minimum width of 5 m (in accordance with the wind turbine manufacturer's recommendations). As noted above, the Consultant anticipates that the erector will assemble its cranes adjacent to one of the wind turbine sites and "walk" them to the second site during the erection process. This will require the upper portion of the access roadway to be a minimum of 7.5 m wide during the construction period.

The Consultant recommends that the access roadway be constructed using compacted gravel in accordance with the wind manufacturers' requirements. The minimum recommended roadway thickness is 300 centimeters ("cm"). The gravel should be compacted to a minimum of 95 percent of its maximum dry density as determined by ASTM D1557.

Construction of the wind turbine site and the access road would be accomplished by conventional means and methods. Clearing of the WWTP site would likely be performed by bulldozers. As the observed surface soils appeared to consist predominantly of sandy materials, blasting is not expected to be required. Once the WWTP site and access roadway is cleared, bulldozers, graders, vibrating rollers, and other conventional earthmoving equipment would be used to grade and compact the access road.

Electric Interconnect

The Consultant observed the electrical infrastructure at the WWTP and the manner in which it is connected to the NSTAR distribution system. The infrastructure that is relevant to the interconnection of the wind turbine generator ("WTG") is between the 480 V, 3000 ampere ("A") main switchboard that serves as the main electrical distribution hub of the WWTP and the NSTAR pole at the edge of the property which serves to connect the WWTP to the NSTAR 23 kV (nominal) overhead distribution system. The existing connection is comprised of the switchboard and a 1500 kVA, 23 kV-to-480/277 V transformer owned by the Town and metering owned by NSTAR, as well as fused switches and lightning arresters on the NSTAR riser pole that is connected to the NSTAR overhead distribution system serving the general area around the WWTP. The switchboard and transformer are connected by underground cables, which are reportedly a part of the WWTP asset, and the transformer and fused switch on the riser pole are connected using an underground cable in a ductbank running under the WWTP parking lot.

In developing a conceptual plan for the electrical interconnection of the two wind turbines, several factors must be taken into consideration. First is that using two 1.5 MW class wind turbines with the potential to generate up to 3 MW at peak output will result in more power than can be transferred across the existing transformer which is rated for 1500 kVA or nominally 1.5 MW even when the WWTP is operating at peak load which is reported to be 774 kW (0.774 MW) over the past year. A second factor is that WTGs in this power class are designed to be connected at a higher voltage than the 480 V that serves the WWTP. The output voltage from a WTG is typically on the order of 600 V depending on the manufacturer and is usually transformed up to a nominal voltage of 23 kV to 35 kV using a transformer at the base of the wind turbine, which may be supplied as part of the wind turbine procurement or by the BOP contractor. The purpose of transforming the voltage up is to reduce the size of the collector system cable that interconnects the WTG and thus reduce electric losses in the cable. A smaller size cable will cost less and the sizing of the cable will take into consideration the balance between cost and system losses. Finally, there is the factor of having the interconnection located "behind the meter" so that credit can be taken for the total generation against other Plymouth electric consumers under the Massachusetts net-metering regulations; refer to the following subsection of this Report. As a result of these factors the interconnection concept will require moving the metering point from 480 V to 23 kV and thus moving the metering point from the existing transformer to the NSTAR riser pole or a new riser, if needed.

Considering the factors discussed above, the conceptual plan of interconnection will include a transformer at the base of each wind turbine to raise the voltage to 23 kV (nominal) to match the NSTAR distribution voltage, a recloser and protective relaying equipment in a pad mounted enclosure at the base of each wind turbine to meet NSTAR system protection requirements, collector system cables routed from the first turbine to the second turbine and then to the point of interconnection on the existing riser pole or on a new pole in that vicinity. The collector system cables are proposed to be three single conductor, aluminum, 25 kV, Size 1/0 cables with ethylene-propylene insulation and an overall PVC jacket and will be direct buried in a trench along with a Size 1/0 ground cable and a fiber optic cable to bring wind turbine control and operating data back to a wind farm control computer (i.e., a single personal computer), which could be located in the WWTP. At the riser pole or poles, the existing cables from the WWTP

and new cables from the WTG will connect to the NSTAR overhead distribution lines through fused switches, one three-phase switch for each circuit.

On the basis of discussions with NSTAR for a wind energy project in Orleans, Massachusetts and a wind energy project in Barnstable, Massachusetts, at the point of interconnection where the line-side of the two switches are connected together, NSTAR will likely require installation of a pole-mounted recloser, 23 kV metering transformers, a radio control link for control of the recloser, and a telephone link to transmit metering data to NSTAR. The latter equipment would be designed and installed by NSTAR.

This electrical interconnection concept is indicated on the "Conceptual Electrical One-Line Diagram, 011582-ESK-10" included as Appendix B of this Report. During the process of negotiating an interconnection agreement with NSTAR, this interconnection concept may need to be modified to accommodate an additional pole for NSTAR equipment, whether NSTAR or Plymouth will own the fused-disconnect switches on the pole(s), or other design details. In addition, Plymouth will have to determine whether it will purchase the existing transformer and cable between the transformer and the riser pole from NSTAR or replace them. Regardless, NSTAR will remove or abandon-in-place the existing WWTP metering at the transformer and Plymouth will be required to compensate NSTAR for its engineering and construction costs.

Net Metering

House Bill No. 3965 ("HB 3965") was filed by the House Speaker during April 2007. HB 3965 proposed to establish under Section 279 net metering in the Commonwealth, whereby net-meters that operate and measure electric energy in two directions and electric energy generated on-site that is not consumed could be sold into the utility grid at a fair price. HB 3965 provided for up to 60 kW of connected renewable energy generation at certain defined small facilities and up to 2 MW of connected renewable energy generation at certain defined large facilities. Subsequently, net metering in the Commonwealth was enacted and signed by the Governor on July 2, 2008 as the Green Communities Act on the basis of statutory changes made by Senate Bill No. 2768 ("SB 2768"); however, the Massachusetts Department of Public Utilities ("DPU") must first adopt new net-metering rules before these changes can take effect. SB 2768 establishes three separate categories of net-metering facilities: Class I facilities are generally defined as systems up to 60 kW in capacity; Class II facilities are generally defined as systems greater than 60 kW and up to 1 MW in capacity that generate electricity from agricultural products, solar energy, or wind energy; and Class III" facilities are generally defined as systems greater than 1 MW and up to 2 MW in capacity that generate electricity from agricultural products, solar energy, or wind energy.

The Commonwealth's investor-owned utilities ("IOUs") must offer net metering. The aggregate capacity of net metering is limited to 1 percent of each utility's peak load. The treatment of customer net excess generation ("NEG") varies for each of the three facility classes and by technology type. In general, for NEG at the end of a billing period, Class I solar and wind facilities, Class II facilities, and Class III facilities receive credit that is somewhat less than the utility's retail rate. Credits may be carried forward to the next month indefinitely, and credits from Class I and Class II wind and solar facilities may be transferred to another customer of the same utility. Credits from Class III facilities may be transferred to other customers with the utility's permission. The Act also allows utility companies to offer up to 50 MW of power-

purchase agreements ("PPAs") to residential and commercial customers over the next two years, subject to approval by the DPU.

With regard to Plymouth, the proposed wind energy project could potentially be categorized as a Class III Large Renewable Generation Facility and further categorized as a Wind Net-Metering Facility. Further with regard to the applicability of net metering for wind energy projects similar to the proposed Plymouth project, the MTC made informal inquiries to the DPU and received the following replies, all of which are subject to future rulemaking.

- In response to the questions - If a municipality had a 3 MW project based on two 1.5 MW wind turbines, would both turbines qualify for net metering? Would they need to be interconnected separately?

  DPU response – "The Act explicitly allows special provisions for net metering at municipal and governmental facilities. As such, municipalities are allowed to net meter per unit, rather than per facility. The Act, however, is silent on how these facilities would be interconnected, and the Department has not made a ruling on this subject. At the very least—for wind, solar, and agricultural facilities—, as long as each unit is less than 2 MW and owned and operated by a municipality/governmental entity, then the unit is available for net metering."

- In response to the question - Can you provide guidance on the potential net metering status of a multi-unit (with each unit < 2 MW) wind generation facility owned and operated by a private third-party at a municipal or governmental location?

  DPU response – "I don't think the Act allows for much flexibility on the issue. I think the only way that the net metering restriction is reduced from a per-facility threshold to a per-unit threshold is if the units are owned or operated by a municipal or governmental entity. Of note, is that the units can either be owned or operated; although I don't think this helps too much with a third-party ownership framework."

Energy Utilization: Generation and Export

As previously suggested in this Report, the electrical usage data provided by Veolia indicates that there is enough of a base load at the WWTP to support the concept of the wind energy plant displacing energy needs at the WWTP.

The electrical energy generated by the wind turbines will vary with the wind resource and there will be periods during which the wind turbines will not generate electricity.

As previously indicated in this Report, the Consultant was provided meteorological data from May 2007 through April 2008, which after analysis (refer to Section 2 and Section 3 of this Report) the data suggest that the P50 twenty-year average net annual energy generation from two GE 1.5sle wind turbines at a 25 percent net capacity factor (refer to Table 14) is estimated to be 6,689 MWh/y.

The operating nature of a wastewater treatment plant is typically a combination of constant electric loads (i.e., base loads) and batch process electric loads (i.e., periodic or cyclic loads). The electrical usage data provided by Veolia suggest that is indeed the case with the WWTP as the raw data in Table 1 and shown in Figure 3 indicate varying peak electric demands.

The electrical usage data provided by Veolia (refer to Section 1 of this Report) indicate that during the same period of May 2007 through April 2008 during which meteorological data was

collected: the WWTP needed 2,069,064 kWh (2,069 MWh/y) of electric energy; minimum peak electric demand was 503 kW; and maximum peak electric demand was 774 kW. Therefore, the electrical usage data for the WWTP suggest that the electrical load factor of the WWTP, where Load Factor equals Average Load divided by Peak Load, was 2,069,064 kWh/8,760 h/y divided by 774 kW, or 30.5 percent during that period.

Accordingly, there will be periods during which the generation from the wind turbines will be greater than the WWTP load thus resulting in a net export of energy, and there will also be periods during which the WWTP load will be greater than the wind turbines output thus requiring that the WWTP continue to purchase energy from NSTAR.

Further analysis of these data to attempt to determine how much of the wind turbines's energy would be used by the WWTP and how much would be exported is not a part of this feasibility study or Report.

We further note that as the WWTP is privately-operated by Veolia under contract to the Plymouth, approval of Veolia is expected to be needed (through possibly an operating agreement modification) to allow energy generated by the wind turbines to be used at the WWTP.

Existing Infrastructure

Documentation and drawings depicting the present underground infrastructure supporting the WWTP were not provided to the Consultant; therefore, the Consultant cannot ascertain if the proposed turbine locations/foundations and the supporting electric collection system might interfere with existing underground sewer lines, water supply lines, settling pond lines, treated-discharge lines, natural gas lines, or other buried infrastructure. The Consultant recommends that during the development process for the proposed wind energy project that such an interference analysis be performed using accurate as-built drawings of the WWTP's supporting infrastructure, and that additional means such as Dig Safe be used to supplement such analysis.

With that said, the current location and layout of the WWTP suggest that all supporting buried infrastructure traverses on the road-side of the WWTP or between the WWTP process building and settling ponds. Under this assumption, the Consultant's conceptual electrical design anticipates that the electrical collection system would travel from the northern wind turbine to the southern wind turbine, northwest to the WWTP process building, and then along the southwest perimeter of the WWTP process building.

Preliminary Work

Work that can be performed in advance of the actual construction of the wind turbines and BOP includes all the site preparation work as identified below.

1. Geotechnical investigations and surveys. Subsurface investigations should be performed to confirm the soil parameters that will be used to determine the foundation requirements and access road design parameters. The Consultant recommends that soil borings be taken at each of the proposed wind turbine locations. Typically with other wind projects with which the Consultant is familiar, a single boring is taken for each turbine location regardless of the type of foundation chosen by the project design contractor. Additionally, one or two test pits should be dug along the proposed access road alignment.

2. Site clearing operations. Limited removal of the existing trees at the wind turbine site and the creation of an access roadway can be performed in advance of the actual wind turbine procurement activities, provided that the locations of the roadways and turbines have been finalized and preferably designed.
3. Grading. Limited grading operations at the WWTP site and along the access road alignment can be performed; however, final grading would be dependent on the proposed project's design.
4. Electrical. Installation of electrical conduits and manholes (including trenching operations) in advance of receiving turbines on site; however, electrical design would need to be far enough along, if not completed, to complete such work.

Section 5
ENVIRONMENTAL CONSIDERATIONS

General Permitting Considerations

A wind turbine project would need to be designed, constructed, and operated in accordance with applicable federal, state, and local regulations, codes, standards, guidelines, policies, and laws. With respect to a wind turbine project in Plymouth, the principal regulatory agencies charged with overseeing these provisions include the U.S. Environmental Protection Agency ("USEPA") and the MDEP. The key permits, approvals, and analyses likely to be needed for a wind energy project in Plymouth are summarized in Table 19 and discussed as follows.

Table 19
Plymouth Wind Energy Generation
Summary of Likely Key Permits, Approvals, and Analyses

Permit/Approval	Responsible Agency	Purpose / Comments
FEDERAL		
Determination of No Hazard to Air Navigation ("DNH")	FAA	To indicate that the wind turbine towers do not interfere with air navigation.
Radio Spectrum Transmission Analysis	U.S. National Telecommunications and Information Administration ("NTIA")	To indicate that the proposed turbine locations will not interfere with communications transmissions, if applicable. This is not likely needed for the proposed project.
National Pollutant Discharge Elimination System ("NPDES") Stormwater Discharge General Permit for Construction	USEPA	For stormwater management during construction activities.
NPDES Stormwater Discharge General Permit for Operations	USEPA	For stormwater management during operations.
Endangered Species / Avian and Bat / Waterfowl Impact Assessments	U.S. Fish and Wildlife Service ("USFWS")	If necessary, to identify project impact on various species. Not expected for this project as there are no endangered species identified in the project area and there are no federal triggers for the proposed project.
Phase I Avian Risk Assessment	USFWS	To assess project impact to birds and bats. MTC has independently performed this in the Cape Cod region but it is unclear if the results of same can be used for Plymouth.

Table 19
Plymouth Wind Energy Generation
Summary of Likely Key Permits, Approvals, and Analyses

Permit/Approval	Responsible Agency	Purpose / Comments
Natural Resource Characterization Report	USFWS	To assess project impact to natural resources. Not expected to be needed.
Breeding Bird Survey	USFWS	To assess project impact to birds and bats. Not expected to be needed.
Wildlife Habitat Evaluation	USFWS	To assess project impact to nearby wildlife. Not expected to be needed.
STATE		
Massachusetts Environmental Policy Act ("MEPA") Review	Massachusetts Executive Office of Environmental Affairs ("MEOEA"), Massachusetts Environmental Policy Act Office	MEPA review will be required; however, it is unlikely that an Environmental Impact Report ("EIR") will be required as the project is not expected to trigger EIR thresholds.
Environmental Notification Form ("ENF")	MEOEA	MEPA review will be required and preparation of an ENF will be required.
Article 97 Review	MEOEA	To assess project impact to Article 97 lands.
Green Community Certification	Massachusetts Department of Clean Energy, Green Communities Division	To establish Plymouth as a Green Community in support of the proposed project as required by the Green Communities Act of 2007.
Vernal Pool Approvals	MDEP	For impacts to vernal pools. None expected for this project as there are no vernal pools identified in the project area at this time.
Project Review	Massachusetts Historical Commission	To assess project impact to historic resources
Project Review	Massachusetts Aeronautics Commission	To assess project impact to regional air navigation.
Conservation Permit	Massachusetts Division of Fisheries and Wildlife ("MDFW")	To assess project impact to wildlife.
LOCAL		
Special Permit	Plymouth, Zoning Board of Appeals	As required by the Wind Bylaw
Planning Board Site Plan Approval	Plymouth	For planning and zoning approval
Architectural Review Approval	Plymouth	For planning and zoning approval
Order of Conditions	Plymouth	For planning and zoning approval
Negative Determination of Applicability	Plymouth	For planning and zoning approval
Building Permit	Plymouth	For planning and zoning approval

Table 19
Plymouth Wind Energy Generation
Summary of Likely Key Permits, Approvals, and Analyses

Permit/Approval	Responsible Agency	Purpose / Comments
Endangered, Rare, or Threatened Species Review	Plymouth Environmental Management Division	In accordance with applicable Town policy
Permit to Open Road	Plymouth	For planning and zoning approval
UTILITY		
Uniform Approval for Distributed Generation Interconnect	NSTAR Electric/ Commonwealth Electric Company	For interconnect approval

Local Approvals

Plymouth has a requirement of the Wind Bylaw whereby a Special Permit is required to be issued by a Special Permit Granting Authority ("SPGA") and for all wind energy projects the Plymouth Zoning Board of Appeals will act in the capacity of the SPGA. The special permit review process is outlined in the Wind Bylaw with the review criteria including consideration of impact on neighborhood character, views and vistas, adequate utilities, and impact on ground/surface water quality and recharge. Furthermore, the process by which a wind energy project must be reviewed as well as submit for review is mandated under the provision of the Plymouth Code, Chapter 205, Section 205-9 titled "Special Permits" (the "Special Permits Bylaw").

Plymouth has an architectural review process as part of its zoning code, under which a review is in place to preserve town character to prevent new construction or alterations that are incompatible with older, existing building styles or that are of inferior quality or appearance; to promote conservation of buildings and groups of buildings that have aesthetic or historic significance; and enhance the social and economic viability of Plymouth by preserving property values and promoting visual attractiveness. A special permit or a building permit cannot be issued without approval of this committee or the deadline for an action has expired.

Massachusetts Approvals

The proposed project involves development of a renewable energy facility, the impacts of which allow certain state permitting agencies to act on the project. The principal regulatory process under which the project will likely be subject would be the MEPA approval. Though the project will not affect greater than 25 acres of land (a MEPA trigger), the project will likely need to undergo review pursuant to Section 11.03 (1) (b) 1 of the MEPA regulations, because the project requires state permitting and the project involves a form of financial assistance from an agency of the Commonwealth. The MEPA jurisdiction extends to all aspects of the project that may cause significant damage to the environment as defined in the MEPA statute. Pursuant to the MEPA (M.G.L. c. 30, ss. 61-62H) and Section 11.06 of the MEPA regulations (301 CMR 11.00), it is unlikely that the proposed project will require preparation of an EIR. Preparation of an ENF will be required, particularly to demonstrate that the potential impacts of the project will not warrant preparation of an EIR.

Land Alteration

The project results in the direct alteration of only a few acres of land some of which has already been partially developed by Plymouth for WWTP site development. The amount of disturbed land is below the mandatory EIR threshold (50 acres) for land alteration; therefore, an EIR should not be required.

Protected Open Space/Article 97 Lands

The project will require physical modifications to public properties. Such activities do not necessarily constitute the conversion of Article 97 lands to a non-Article 97 use, nor do such activities constitute the release of an interest in land held for conservation purposes; however, other aspects of the project may result in conversion of Article 97 lands. These issues should be reviewed by appropriate Plymouth officials.

Wetlands

The project will not result in alteration of any wetlands. It should be noted however that there are wetlands and vernal pool in the nearby region.

Rare Plant Species

Through research of available public databases, the Consultant could not identify rare plant species at the WWTP site. In the event that a rare plant is identified at the WWTP site, the project may need to develop a transplantation program and conservation management plan for impacts to rare plants, as well as require a Conservation Permit from the Massachusetts Division of Fisheries and Wildlife.

Rare or Endangered Species

Through research of available public databases, the Consultant could not identify rare or endangered species at the WWTP site.

Air Quality Mitigation

The project will produce air quality benefits for the Commonwealth. The project will be required to avoid or minimize negative impacts to the greatest feasible extent, and to mitigate any unavoidable impacts. As discussed above, the project permitting review process should ensure that appropriate mitigation is developed for any unavoidable impacts. It is expected that mitigation commitments, if any, would become permit conditions as the project moves through the permitting process.

Operations Monitoring & Decommissioning

The Consultant anticipates that certain government wildlife and resource management agencies, including the MEOEA, the Massachusetts Audubon Society, and the Conservation Law Foundation, will request that the project provide post-construction monitoring of impacts to birds and bats. Development of a monitoring program will provide evidence to evaluate the accuracy of the predictions for minimal impacts to wildlife, as well as scientifically useful information in a much broader context of the Commonwealth's energy and environmental policies. The Consultant anticipates that the project will need to perform this post-construction monitoring

commensurate with the size and potential impacts of the project and consistent with the requirements of any applicable permits as a baseline-level of research.

The Consultant anticipates that the project will be expected to develop a decommissioning plan as part of the local review of the project.

Areas of Cultural or Historic Significance

The WWTP site is a pre-disturbed, industrial site; and, potential conflicts with areas of cultural or historic significance are expected to be minimal. While certain sites in downtown Plymouth is included in the State Register of Historic Places, these sites are located more than 3 km from the WWTP site.

Federal Approvals

There are certain other key permits and approvals that should be discussed, most notably the FAA DNH. Under FAA regulations, application for a DNH must be made to the FAA for: (a) any construction or alteration exceeding 200 ft (61 m) above ground level; (b) any construction or alteration within 20,000 ft (6.1 km) of a public use or military airport which exceeds a 100:1 surface from any point on the runway of each airport with at least one runway more than 3,200 ft (975 m), within 10,000 ft (3.5 km) of a public use or military airport which exceeds a 50:1 surface from any point on the runway of each airport with its longest runway no more than 3,200 ft (975 m), or within 5,000 ft (1.5 km) of a public use heliport which exceeds a 25:1 surface; (c) any highway, railroad or other traverse way whose prescribed adjusted height would exceed the above noted standards; (d) when requested by the FAA; or (e) any construction or alteration located on a public use airport or heliport regardless of height or location. These requirements are part of FAA Advisory Circular AC 70/T460-1K and -2K. Upon application for a DNH, FAA performs an obstruction evaluation for the proposed structure, which in the case of the Plymouth project would be the wind turbines and prior to construction possibly the construction cranes.

Refer to the Airspace Evaluation discussion in Section 4 of this Report. Obstruction lighting may be required as there are no other permanent tall towers in the vicinity. The project is not expected to employ lighting during daytime hours and may likely use medium-intensity red obstruction lights with the longest allowable off-cycle during nighttime hours. Lighting requirements will need to balance visual concerns and potential impacts on birds and bats (some of which may be attracted to certain types of lighting) with the need to ensure the safety of the structures, particularly with respect to aviation. The project site is not close to an airport; however, the project may penetrate certain aviation spaces. The FAA will review wind turbine location and height, and issue essentially binding recommendations on lighting as part of its "Part 77" review process. The FAA process is intended to balance consideration of safety, aesthetics, and environmental impact. The project would be required to implement the least intrusive lighting plan allowable by the FAA to ensure an appropriate level of aviation safety.

General Environmental Considerations

Limited research through public and some private databases suggests that the potential installation site at the WWTP site will not impact any rare or endangered species. Observations while walking about the WWTP site did not find any wetlands or vernal pools or evidence of the

earlier existence of such. However, there are wetlands and signs of vernal pools in the general vicinity area.

While the Consultant did not observe obvious environmental concerns during the Consultant's visits to the WWTP site, the Consultant does recommend environmental surveying. The wind turbine locations are at least 195 m from the nearest property line, which in the Consultant's opinion should provide a sufficient sound buffer to satisfy the noise provision of the Wind Bylaw. The closest residential receptors are located approximately 400 m from the potential wind turbine locations. At this time the Consultant does not foresee any significant environmental, communications, or cultural hurdles; however, a portion of Plymouth is designated as a Core Habitat and the applicability of this designation with regard to the WWTP site should be confirmed.

Avian Impacts

The project may be required to prepare a Wildlife Habitat Evaluation, Natural Resource Characterization Report, Breeding Bird Survey, and Phase I Avian Risk Assessment, with the latter likely requested by USFWS. MTC has performed Phase I Avian Assessments for the Cape Cod region as well as other regions in the Commonwealth, the results of which may be useful for the Plymouth project. It is not anticipated that the project would result in a materially significant take of rare birds or bats.

Noise

As part of the local review process, the project will likely need to conduct a study of project-related noise impacts and develop sound contours for the project with emphasis on residential structures that may fall within the sound contours associated with the project. The Consultant completed a preliminary evaluation of sound contours based on the GE 1.5sle wind turbine. Figure 11 represents a contour map of the estimated sound pressure levels that would be generated by the wind turbines when the hub height wind speed is 14 m/s (when the wind turbine is approaching rated power output).

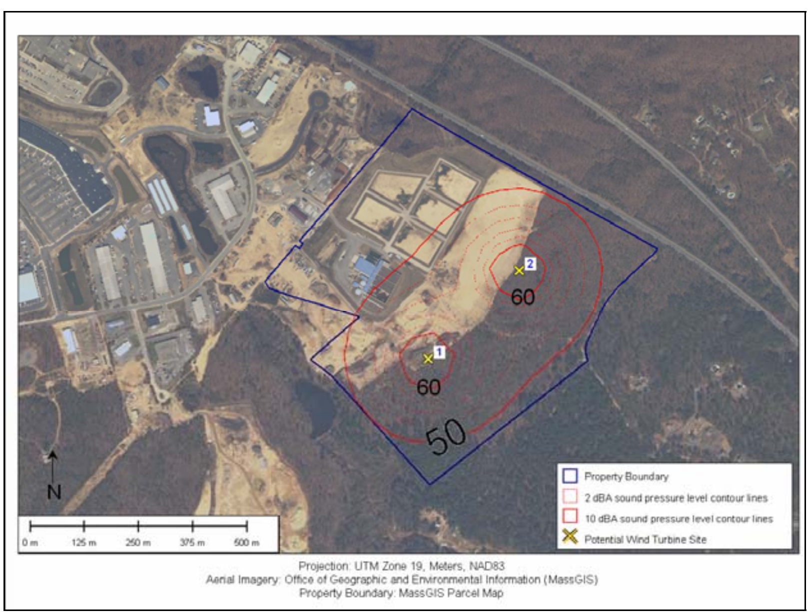


Figure 11 - Estimated Sound Contour Levels at WWTP Site, GE 1.5sle Wind Turbines

As shown, the sound pressure level from a wind turbine at a distance equal to the distance from the proposed turbine locations to the nearest WWTP site property line is estimated to be approximately 50 dBA. Based on available information, the estimated sound pressure level meets the Wind Bylaw in that sound from a wind turbine cannot exceed 60 dBA measured at the nearest property line. At wind speeds higher than 14 m/s, noise from a wind turbine become less noticeable because background noise associated with the wind itself increases and tends to cover or mask that being generated by the turbine. While the Consultant did not record or monitor ambient noise levels at the WWTP site, it is noted that a turbine sound pressure level of 50 dBA at the nearest WWTP site property line with an ambient noise level of 40 dBA would result in the sound pressure level at the property line becoming 50.4 dBA. This estimated result at the WWTP property line meets the MDEP noise policy previously discussed; however, this is highly dependent on the actual ambient noise level of the site. The Consultant recommends that a more detailed study of analysis of ambient noise and potential noise impacts be undertaken

Photo Visualizations

To understand what a 1.5-MW-class wind turbine may look like at the WWTP site, the Consultant developed several photo visualizations, or simulations, of a 1.5-MW-class wind turbine located on the prospective site from various locations in the community, which appear in Appendix C of this Report. The wind turbines used in the images have a hub height of 80 m and a rotor diameter of 77 m. The top-of-blade height is therefore 118.5 m. The photo simulations provided are not valid for turbine models with significantly different dimensions.

Photo visualizations were developed from photographs of nearby representative positions from which the proposed wind turbine is expected or suspected to be visible, based on the topography and vegetation. The investigated locations were limited to public land and roads. The Consultant did not attempt simulations from private lands for this investigation. The currently proposed wind turbine locations described in this Report were used in the visualization.

The photographs were taken in June 2008, which corresponds with maximum leaf density on deciduous vegetation. The proposed wind turbines are expected to be seen from additional vantage points in the winter when the deciduous trees lose their leaves. Each wind turbine's distance above the horizon as shown in the photo visualizations are based on the Consultant's estimation of the relative elevation difference between the vantage point and the wind turbine site using publicly-available digital elevation model data with a 10 m spatial resolution. Thus the actual views may differ from those shown here.

Since the primary wind direction is southwest (about 210 degrees from true north), the turbines in the photos are oriented to face into this direction. The sun angle, light intensity level, and shadows on the turbines have been adjusted to most closely match the local conditions at the time the photo was taken. The WindFarm software program (ReSoft Ltd.) was used to create all photo simulations.

Figure C-1 shows the vantage points and proposed wind turbine locations for which photo visualizations were developed. Figures C-2 through C-6 show the photo visualizations for each vantage point. In Figures C-4 through C-6, the wind turbines would not be visible from the shown vantage point; therefore, a wire frame of the topography and wind turbines is presented to illustrate the approximate location of the turbines behind the obstructions shown in the photo.

Communications Infrastructure

Wind turbines, like all tall structures, can create interference or degradation of certain communication signals if they are located in the line-of-sight of any communications equipment such as microwave, radio, or satellite dishes. Figure 12 shows the location of known communications towers within 10 km of the WWTP site. The closest communications equipment to the WWTP site are two cellular towers approximately 1 km to 1.5 km to the west and northwest. Analysis of line-of-sight signal interference is beyond the scope of this review. Further analysis is required, which would take into account the proposed turbine dimensions, turbine location, and transmittal paths of various types of communication signals in the area.

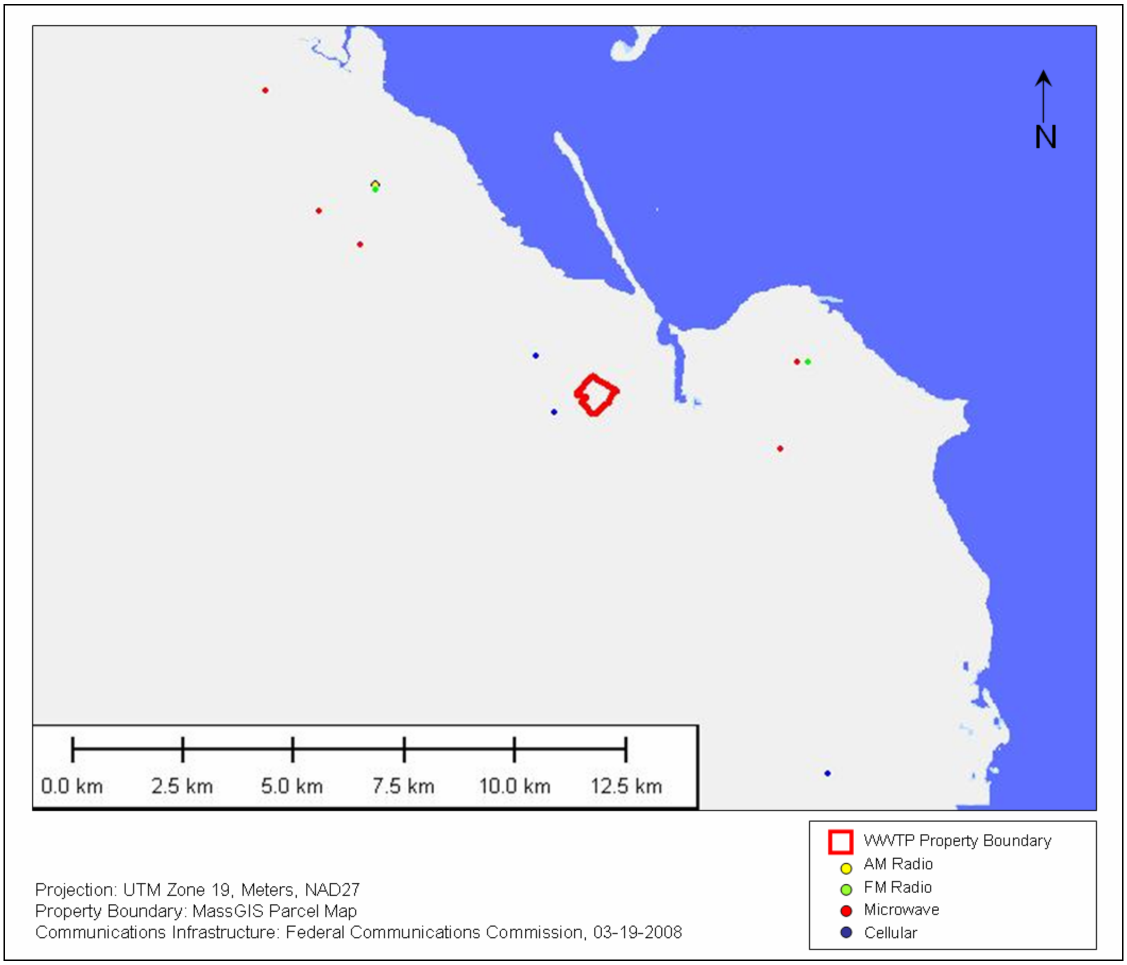


Figure 12 - Location of Select Communications Infrastructure near the WWTP

Shadow Flicker

Shadow flicker can be generated by the rotating blades of a wind turbine during certain ambient lighting conditions, which can cause an annoyance until the sun changes position in the sky. Based on the Consultant's previous experience with shadow flicker analyses, buildings located more than 300 m from a megawatt-size wind turbine are likely to experience minimal shadow flicker impact and such impact is limited to periods when the sun is low and shadows tend to be

diffuse. Receptors located 200 m to 300 m from a wind turbine may experience shadow flicker up to 50 hours per year, depending on the amount of cloud cover in the area. There are no residential or commercial buildings within 300 m of the proposed wind turbine locations; however, the WWTP is located approximately 200 m from the proposed turbine locations and is the most likely building in the area to be affected by shadow flicker. Because of the relative locations of the proposed wind turbines and the WWTP, any potential shadow flicker impacts will likely be limited to morning. Ultimately, the extent of shadow flicker impact at the WWTP depends on the size of the wind turbine, season, time, surrounding terrain and obstructions, cloud cover, wind speed and direction, and the location of windows or other occupied areas of concern. While a site-specific shadow flicker analysis is beyond the scope of this feasibility study and Report; such a study could be completed at a later stage in the project development process.

Advance Permitting Activities

As previously discussed in this Section of the Report, there is a number of permitting and approval activities that will be required for the proposed wind energy project to be developed. In general the majority of these permits and approvals can be applied for in advance on the basis of generic project and wind turbine information; however, there are certain permits and approvals that can only be applied for after the actual wind turbines (i.e., manufacturer and model) have been selected or procured, so that key technical data can be provided in their applications.

For example, the FAA DNH for each turbine site can be applied for on the basis of an assumed MTH for each turbine and will not require a significant amount of advance engineering/design; but, it will require identification of the exact location for each wind turbine. In contrast, the Special Permit will require a fair amount of advance engineering to prepare the various submittals required by the Special Permits Bylaw. Site plans will need to be prepared with the general arrangement of equipment, foundations, access roads, and electric cabling.

An electric one-line diagram to support construction and application for interconnect with NSTAR will need to identify certain technical information that can only be known after a wind turbine has been selected.

Regardless of what entity (e.g., Plymouth, contractor) develops the proposed wind energy project, in the context of those permits, approvals, and analyses identified in Table 18, the following permitting and approval process is suggested.

1. Finalize wind turbine locations.
2. Initiate FAA DNH approval process seeking approval for highest potential turbine height.
3. Initiate MEPA review process.
4. Initiate Special Permit approval process.
5. Initiate Green Communities Certification process.

To assist in identifying the local permitting and approvals process, the Wind Bylaw and the Special Permits Bylaw are attached to this Report as Appendix D.

Permitting Schedule

Barring unforeseen circumstances and potential intervener delays, the Consultant expects that from six to twelve months will be required to acquire the key environmental permits and approvals needed to construct the proposed wind energy project.

Section 6 PLANNING LEVEL OPINION OF PROBABLE CAPITAL COSTS AND O&M COSTS

Capital Costs

For this feasibility study the Consultant has estimated equipment, material, and transportation pricing based on published pricing and supplemented by information from the Consultant's proprietary cost databases (the "Cost Databases"), which contain information on similar equipment purchased for other projects with which the Consultant are familiar. For installation, the Consultant estimated labor hours mainly from the Cost Databases and adjusted these based on the project's location, site conditions, and expected labor productivity. Additionally, where applicable the Consultant took into consideration recent cost and pricing information with regard to several small wind energy projects in Massachusetts. In general, the planning level capital costs presented in this Section of the Report can be considered as -5 percent/+30 percent estimates.

Turbine Capital Costs

The two GE 1.5sle turbines as referenced in this Report are estimated to cost approximately $5,218,000 for the wind turbines and towers (FOB manufacturer) without transportation. The estimated cost includes an FAA-required aviation beacon, SCADA system, two-year manufacturer warranty, and cold weather package believed to be suitable for the WWTP site. It should be understood that final wind turbine cost will depend on a number of factors such as warranty, options purchased, market factors, and contract negotiations. The estimated cost is based on engineering judgment as opposed to an actual quote from GE. The Consultant has attempted to account for pricing premiums applied by turbine manufacturers for the small quantity, one-time purchase represented by this project. There is a high degree of pricing uncertainty due to the dynamic turbine purchase market currently prevailing in the wind industry. Several wind turbines other than those identified in this Report may also be suitable for the WWTP site. Costs for comparable machines may differ from those mentioned in this Report; however, on a unit cost basis ($/kW), these figures can be viewed as representative of wind turbines in these capacity ranges. To obtain more accurate cost estimates, a request-for-proposals is typically issued following feasibility and pre-development studies. More accurate costs based on the specific characteristics, conditions and requirements of the project can then be obtained from a review of proposal submissions.

Turbine Transportation Costs

Transportation costs are estimated to cost approximately $714,000 for the two GE 1.5sle turbines discussed in this Report, excluding road modifications if required. The transportation estimate is based on recent costs for the transportation of similar equipment taking into account the typical origination of the various wind turbine components. A mix of ocean freight and truck transport was assumed depending on the origination point of the equipment, and the "best known methods" for transport in the region. These costs will vary depending on the exact origin of each piece of equipment and on the exact transportation methods and routes used by the wind turbine

supplier or transportation contractor. Road modifications are not included in the cost estimate because the need and extent if necessary of such modifications are unclear; such costs may likely be absorbed by project contingency.

Civil, Sitework, and Erection

Civil, sitework, and erection costs encompass the scope of civil and sitework discussed in Section 4 of this Report. This item includes site preparation (including removal of trees and site grading), excavation and backfill for wind turbine foundations, concrete work, the installation a compacted gravel access roadway (from the existing WWTP area paving to the wind turbine sites, and pad mounted electrical equipment at the wind turbines. Modifications to the main WWTP driveway entry and/or off-site roadway modifications are not included in this item. Labor costs are based on regional (Massachusetts) labor rates. The estimated costs for civil, sitework, and erection are based on the Consultant's experience as opposed to an actual price quotes from contractors.

Electrical Systems

Electrical systems costs encompass the scope of electrical work discussed in Section 4 of this Report. These items include the costs for the step-up transformers, pad-mounted reclosers, material and installation of the collector system cable, ground conductor, and fiber optic cable, and riser pole and fused switch at the point of interconnection with NSTAR. An estimate has been included as a separate line item for NSTAR costs at the point of interconnection for primary metering, a recloser, and communications; this value will ultimately be determined by NSTAR based on its design of these facilities as part of a formal interconnection agreement process. The estimated costs for electrical systems are based on the Consultant's experience as opposed to an actual price quotes from contractors.

Total Construction Costs

The estimated total construction cost is the sum of all of the costs described above.

Owner's Costs

Owner's project costs are in addition to the constructor probable costs. These costs include the owner's (or developer's) costs for project management, administration, permitting, fees and studies to support NSTAR electrical interconnect, geotechnical investigations, airspace evaluations, noise evaluations, additional environmental evaluations, interfacing with municipal agencies, land and right of way acquisition, local benefits, costs for construction of the electric interconnection, spare parts, insurance, taxes, legal costs, accounting, working capital allowances, and similar costs not included in the construction contractors scope. These costs vary significantly from project to project and can be from 15 percent to 45 percent of the construction cost. The owner/developer should evaluate these costs based on its experience and include a realistic value in its financial analysis. For the purposes of this feasibility study the Consultant has used approximately 15 percent, plus certain anticipated costs for the key items identified above in this paragraph, on the basis of costs observed with certain other wind energy projects in Massachusetts with which the Consultant is familiar.

Contingency

A project contingency allowance for unknown costs is normally included. On the basis of the Cost Databases, this allowance is commonly at least 5 percent to 10 percent of the total construction costs. To provide a breakdown of procurement and construction contingency, the Consultant has included an allowance for material and equipment costs and for construction costs. For the purposes of this feasibility study the Consultant has arbitrarily increased contingency to approximately 15 percent of anticipated project costs on the basis of its experience with similar project within Massachusetts.

Total Estimated Project Costs (without Finance Costs)

This is the total estimated cost of the proposed project and is the sum of the total construction costs and other project costs described above. This total does not include finance costs or cost of a construction loan.

Summary of Planning Level Capital Costs

Table 20 below summarizes the Consultant's opinion of the proposed wind energy plant's probable planning level capital costs.

Table 20
Summary of Opinion of Probable Planning Level Project Capital Costs (1)
for Plymouth's Two-Turbine Project

Item		Cost for Two GE 1.5sle
Subtotal for wind turbine generator(2)		$5,218,000
Subtotal for civil/sitework and turbine erection		$820,000
Subtotal for electrical systems and erection		$485,000
Subtotal for wind turbine transportation		$714,000
Subtotal - Construction Costs		**$7,237,000**
Owner's Costs, including engineering & permitting		$1,188,000
Subtotal – Project Costs		**$8,425,000**
Subtotal for NSTAR electrical systems (3)		$150,000
Project Contingency		$1,285,000
Total Estimated Project Costs		**$9,860,000**
Installed Cost per Kilowatt ($/kW)		***$3,290***

***Notes**:*

1. In 2008 dollars.

2. Quotes from turbine suppliers are not available. Value indicated is an estimate for a small volume, one time order. A high degree of pricing uncertainty exists given current market conditions.

3. Electrical equipment to interface with the utility grid as required depending upon the particular final interconnect design by NSTAR.

Operations and Maintenance Costs

Turbine

Recurring turbine operations and maintenance ("O&M") costs will vary depending on a number of factors. Turbine O&M costs vary significantly depending on the O&M strategy employed, the reliability of the equipment and the roles and responsibilities of the equipment manufacturer in providing service and warranty repairs. Turbine O&M costs generally are divided into the following categories:

- Operations (e.g., resetting wind turbines which have tripped off-line due to a fault).
- Scheduled, preventive maintenance on the wind turbines and other equipment (e.g., routine oil changes and inspections of transformers).
- Unscheduled maintenance including activities ranging from simple component replacements to major component repairs.
- Periodic component overhauls and scheduled replacements (as specified by wind turbine supplier).

The first three categories occur during the course of each year while the fourth category occurs at periodic intervals over the life of the project.

For purposes of this evaluation, recurring turbine O&M costs have been estimated for an assumed warranty period (first two years) and escalating in subsequent years. These turbine O&M estimates are not specifically for the wind turbines referenced in this Report but are representative of typical 1,500 kW wind turbines, since the analysis of a specific wind turbine is not warranted by the scope of this study. Individual components of this total cost will vary. Most notably, the repair costs of a wind turbine are expected to increase above inflation.

Table 21 indicates how O&M costs are expected to change over the project life. These estimates assume the purchase of a two-year, all-inclusive turbine O&M warranty.

Table 21
Estimated O&M Costs of
Typical Two-Turbine Project

O&M Item	Year 1-2	Year 3-5	Year 6-10	Year 11-15	Year 16-20
Typical 1.5 MW wind turbine – Two Turbines					
Operations, scheduled and unscheduled maintenance, warranty (first two years)	$77,000	$82,000	$87,000	$96,000	$103,000

Notes:
1. *Constant 2008 Dollars*

The greatest unknowns with near-term recurring costs are what service and warranty provisions and payments are negotiated as part of the wind turbine purchase. The biggest unknowns associated with long-term recurring costs are the reliability and lifetime of major wind turbine components such as gearboxes, generators, and blades. This is especially true for a single-wind

turbine installation. For large projects, the reliability and replacement costs can be estimated with reasonable certainty on an average project-wide basis. While some wind turbines have better than average reliability and others worse than average, a single wind turbine with only slightly better or worse reliability than the fleet-wide average may result in much lower or higher costs than average and these costs are not offset by the averaging affects of a larger project. This long-term recurring cost uncertainty can be reduced by entering into longer than two-year warranty contracts; however, few wind turbine manufacturers offer all-inclusive warranty periods longer than five years. Machinery insurance can also be purchased to shelter the owner from some amount of risk.

Wind energy plant maintenance would be categorized in three distinct areas: preventive, corrective, and predictive. It's conceivable that Plymouth employees or the WWTP's third-party operators could perform some preventive maintenance and some minor corrective maintenance; but, the Consultant does not recommend this. Most corrective maintenance, major preventive maintenance, and all predictive maintenance would be provided by outside contractors or the wind turbine manufacturer. Maintenance management is expected to be performed using industry-standard computer based planning software, which would include programming the manufacturer's recommended maintenance requirements into the software. Routine preventive maintenance activities would be performed by technicians assigned to day-to-day work. The wind turbine would generally run unattended, and have a 6-month scheduled service interval.

The wind energy plant would need a long term major maintenance plan to schedule preventive maintenance outages. Major equipment overhaul – either preventive or corrective – is expected to be contracted to the manufacturer or a qualified off-site contractor. The Consultant expects that that the wind turbine would be maintained under a long-term service contract.

Other O&M Costs

The Consultant expects that Plymouth or its third-party operator will maintain an appropriate set of spare parts on hand to achieve the availability assumed in the net energy forecast. For space reasons, certain major items may be inventoried in other nearby facilities. Spare parts could be stored in a separate secured room nearby – possibly in one of the maintenance buildings in the WWTP area.

Section 7 ASSUMPTIONS AND REFERENCES

Principal Considerations and Assumptions

In the preparation of this Report and the opinions presented in this Report, the Consultant has made certain assumptions with respect to conditions which may exist or events which may occur in the future. While the Consultant believes these assumptions to be reasonable for the purpose of this Report, they are dependent upon future events, and actual conditions may differ from those assumed.

In addition, the Consultant have used and relied upon certain information provided to us by sources which the Consultant believe are reliable. While the Consultant believe the use of such information and assumptions to be reasonable for the purposes of this Report, the Consultant offer no other assurances with respect thereto and some assumptions may vary significantly due to unanticipated events and circumstances. To the extent that actual future conditions differ from those assumed in this Report or provided to us by others, the actual results of the Consultant's analyses will vary from those projected in this Report. This Report summarizes the Consultant's work up to the date of the Report; thus, changed conditions occurring or becoming known after such date could affect the material presented to the extent of such changes.

References & Data Sources

The following references and data sources were utilized for this study:

1. Manwell, James et. al., University of Massachusetts Amherst Renewable Energy Research Lab, *Wind Data Report Plymouth June 1, 2007 – August 31, 2007*, October 18, 2007; and *Wind Data Report Plymouth September 1, 2007 – November 30, 2007*, January 22, 2008; and *Wind Data Report Plymouth December 1, 2007 – February 29, 2008.*
2. *New England Wind Map*, TrueWind Solutions.
3. Wind resource data collected at Plymouth site by the University of Massachusetts Renewable Energy Research Laboratory.
4. NSTAR Electric/Commonwealth Electric Company, *Standards for Interconnection of Distributed Generation*, DTE0238 Tariff, April 2004.
5. Town of Plymouth Code, Chapter 2005 *Zoning Bylaw*: Section 205-9 *Special Permits* and Section 205-73 *Wind Energy Facilities*.
6. *Massachusetts Environmental Policy Act Guidelines (various)*, Massachusetts Executive Office of Environmental Affairs.
7. *Massachusetts DEP Guidelines (various)*, Massachusetts Department of Environmental Protection.
8. *Code of Federal Regulations ("CFR") (various)*, U.S. Government Various Agencies.
9. *Model Amendment to a Zoning Ordinance or By-law: Allowing Wind Facilities by Special Permit,* Massachusetts Executive Office of Environmental Affairs.

APPENDIXES

APPENDIX A – WIND TURBINE POWER CURVES

APPENDIX B – AIRSPACE ANALYSIS

APPENDIX C – PAVE PAWS WIND TURBINE ANALYSIS

APPENDIX D – ELECTRICAL ONE-LINE DIAGRAM

APPENDIX E – PHOTO VISUALIZATIONS

APPENDIX F – PLYMOUTH CODE: WIND BYLAW AND SPECIAL PERMITS BYLAW

APPENDIX A
WIND TURBINE POWER CURVES

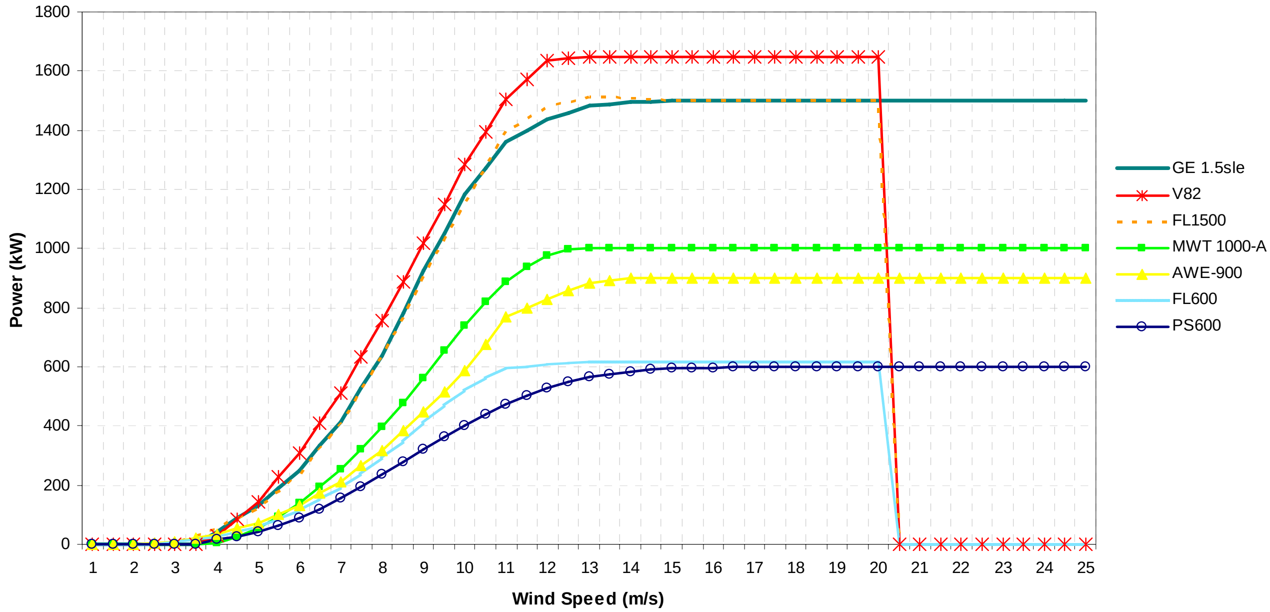


Figure A-1. Representative Wind Turbine Power Curves (1.225 kg/m^3 air density)

Table A-1
Representative Wind Turbine Power Curves (1.225 kg/m^3 air density)

Wind Speed Bin Center, m/s	GE 1.5sle Power Output, kW	V82 Power Output, kW	FL1500 Power Output, kW	MWT 1000-A Power Output, kW	AWE-900 Power Output, kW	FL600 Power Output, kW	PS600 Power Output, kW
0.5	0	0	0	0	0	0	0
1.0	0	0	0	0	0	0	0
1.5	0	0	0	0	0	0	0
2.0	0	0	0	0	1	0	0
2.5	0	0	0	0	5	1	0
3.0	0	0	5	0	9	8	0
3.5	0	0	30	1	21	15	0
4.0	43	28	55	6	33	26	19
4.5	87	86	87	24	53	42	27
5.0	131	144	119	54	73	61	42
5.5	191	227	177	93	103	85	63
6.0	250	309	234	140	133	116	88
6.5	333	410	321	194	173	151	118
7.0	416	511	407	254	213	190	155
7.5	528	635	521	321	265.5	237	194
8.0	640	758	634	396	318	290	236
8.5	782	888	769	477	382.5	347	280

Table A-1
Representative Wind Turbine Power Curves (1.225 kg/m^3 air density)

Wind Speed Bin Center, m/s	GE 1.5sle Power Output, kW	V82 Power Output, kW	FL1500 Power Output, kW	MWT 1000-A Power Output, kW	AWE-900 Power Output, kW	FL600 Power Output, kW	PS600 Power Output, kW
9.0	924	1017	904	564	447	411	322
9.5	1053	1151	1029	653	517	470	363
10.0	1181	1285	1154	741	587	519	401
10.5	1270	1395	1275	821	677	564	438
11.0	1359	1504	1396	888	767	594	472
11.5	1398	1571	1438	940	798	602	502
12.0	1436	1637	1480	976	829	609	528
12.5	1459	1644	1496	999	856	615	549
13.0	1481	1650	1512	1000	883	615	564
13.5	1488	1650	1511	1000	892	615	575
14.0	1494	1650	1510	1000	900	615	584
14.5	1497	1650	1505	1000	900	615	591
15.0	1500	1650	1499	1000	900	615	596
15.5	1500	1650	1500	1000	900	615	597
16.0	1500	1650	1500	1000	900	615	598
16.5	1500	1650	1500	1000	900	615	600
17.0	1500	1650	1500	1000	900	615	602
17.5	1500	1650	1500	1000	900	615	601
18.0	1500	1650	1500	1000	900	615	600
18.5	1500	1650	1500	1000	900	615	600
19.0	1500	1650	1500	1000	900	615	600
19.5	1500	1650	1500	1000	900	615	600
20.0	1500	1650	1500	1000	900	615	600
20.5	1500	0	0	1000	900	0	600
21.0	1500	0	0	1000	900	0	600
21.5	1500	0	0	1000	900	0	600
22.0	1500	0	0	1000	900	0	600
22.5	1500	0	0	1000	900	0	600
23.0	1500	0	0	1000	900	0	600
23.5	1500	0	0	1000	900	0	600
24.0	1500	0	0	1000	900	0	600
24.5	1500	0	0	1000	900	0	600
25.0	0	0	0	0	0	0	0

APPENDIX B
AVIATION ANALYSIS

AVIATION SYSTEMS INC.

Date: JUN 0 5 2007

To: Chris Clark
Massachusetts Tech Collaborative
75 North Drive
Westborough, MA 01581

ASI #: 07-N-0448.007
Client Site ID: Plymouth WWTP
FAA #:

We are sending you herewith the following via:

☑ **US Mail** ☐ **Overnight** ☐ **Fax** ☑ **Email** ☐ **2nd Day**

☑ ASI FAR Part 77 Airspace Obstruction Report
☐ Search Area Study Report
☐ Copies of our filing(s) with FAA and/or State
☐ Responses from FAA and/or State
☐ ASI Opinion Letter
☑ Quad Chart
☑ See attachments for Airport Runway data and/or AM Stations(s)
☐ Certified Survey

Comments:

Sincerely,

Aviation Systems, Inc.
By: [signature]

2510 W. 237th Street • Suite 210 • Torrance, CA 90505
Tel: 310.530.3188 • Fax: 310.530.3850 • email: crisj@aviationsystems.com • www.aviationsystems.com

AVIATION SYSTEMS, INC.
Phone: 310-530-3188 Fax: 310-530-3850
crisj@aviationsystems.com
www.aviationsystems.com

FAR PART 77 AIRSPACE OBSTRUCTION REPORT

To:

Chris Clark
Massachusetts Tech Collaborative
75 North Drive
Westborough, MA 01581

Date: June 5, 2007

Location: Plymouth, MA
Client Case No: Plymouth WWTP
ASI Case No: 07-N-0448.007

SUMMARY OF FINDINGS:

At this location any structure over 200 feet AGL will have to be filed with the FAA. A structure up to 316 feet AGL should receive a routine approval. A structure from 316 to 354 feet AGL should be approvable but require extended study. Refer to Findings and Comment Section for additional information.

SITE DATA:

Structure: Wind Turbine

Coordinates: 41°-55'-36.38" / 070°-38'-25.30" **[NAD 27]**
41°-55'-36.75" / 070°-38'-23.42" **[NAD 83]**

Site Ground Elevation: 144 ' **[AMSL]**
Studied Structure Height (with Appurtenances): 397 ' **[AGL]**
Total Overall Height: 541 ' **[AMSL]**

SEARCH RESULTS:

- The nearest public use or military air facility subject to FAR Part 77 is Plymouth Muni Airport.
- The studied structure is located 3.82 NM / 23,223 feet East (071 ° True) of the Plymouth Muni Airport Runway 33.
- Other public or private airports or heliports within 3 NM: ☐ None ☑ Printout attached
- AM radio station(s) within 3NM: ☑ None ☐ Printout attached

Highlighted AM stations on printout require notice under FCC Rules and Policy (Ref.: 47 CFR 73.1692).

ASI Case No: 07-N-0448.007

FINDINGS

- **FAA Notice (Ref.: FAR 77.13 (a)(1); FAR 77.13 (a)(2) i, ii,iii):**
  - ☐ Not required at studied height.
  - ☑ Required at studied height.
  - ☑ The No Notice Maximum height is 200 feet AGL.

IMPORTANT: Our report is intended as a planning tool. If notice is required, actual site construction activities are not advisable until an FAA Final Determination of No Hazard is issued.

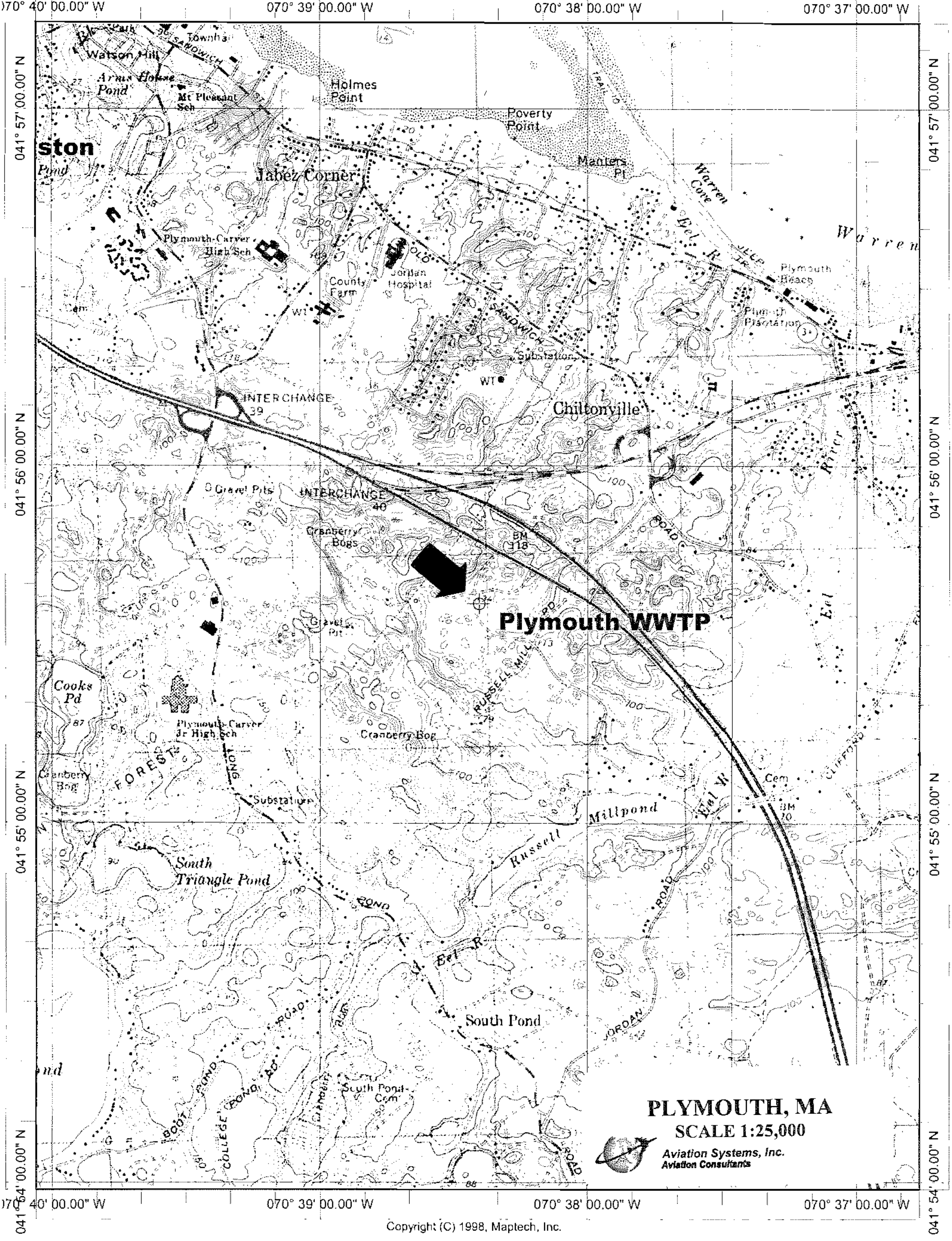
- **Obstruction Standards of FAR Part 77 (Ref.: FAR 77.23 (a)(1),(2),(3),(4),(5)):**
  - ☐ Not exceeded at studied height.
  - ☑ Exceeded at studied height and Extended Study may be required.
  - ☑ Maximum nonexceedance height is 316 feet AGL.
- **Marking and Lighting (Ref.: AC 70/7460-1K, Change 1):**
  - ☐ Will not be required.
  - ☑ Will be required at studied height, if structure exceeds:
    - ☑ 200 feet AGL
    - ☑ Obstruction Standard
- **Operational Procedures (Ref.: FAR 77.23 (a)(3), (4); FAA Order 7400.2; FAA Order 8260.3B):**
  - ☑ Not affected at studied height (FAA should issue a Determination of No Hazard.)
  - ☐ Affected at studied height and the FAA will consider the studied structure to be a hazard to air navigation.
  - ☐ Maximum height that would not affect operational procedures is ______ feet AMSL.

Conclusions/Comments

The BOSTON/NORTH TRURO Joint Use Long Range Radar Site is located 27.03 NM from the proposed structure. The Air Force has published a memo establishing the following policy: "The DOD/DHS Long Range Radar Joint Program Officee Interim Policy is to contest any establishment of windmill farms within radar line of site of the National Air Defense and Homeland Security Radars." Therefore, the FAA may object to this/any proposal, until an individual assessment is performed.

Actions:

ASI will file with FAA Region and State ☐ Yes ☑ No



070° 40' 00.00" W
070° 39' 00.00" W
070° 38' 00.00" W
070° 37' 00.00" W
041° 57' 00.00" N
041° 56' 00.00" N
041° 55' 00.00" N
041° 54' 00.00" N
Plymouth WWTP
Watson Hill
Holmes Point
Poverty Point
Manters Pt
Jabez Corner
Warren Cove
Plymouth-Carver High Sch
County Farm
Jordan Hospital
Plymouth Beach
Chiltonville
INTERCHANGE 39
INTERCHANGE 40
Gravel Pits
Cranberry Bogs
Cooks Pd
Plymouth-Carver Jr High Sch
Cranberry Bog
FOREST
Substation
Millpond
Russell
South Triangle Pond
Eel R
South Pond
South Pond Cem
PLYMOUTH, MA
SCALE 1:25,000
Aviation Systems, Inc.
Aviation Consultants

Airports with Runways

Search Latitude: 41-55-37 **Search Radius:** 3
Search Longitude: 070-38-23 **Height (MSL):**

ID	Name	City	State	ARP Lat	ARP Long	Type	Rways	Primary	RwyLat	RwyLong	Elev.	Dist/NM	Dist/feet	Bear
1MA0	JORDAN HOSPITAL	PLYMOUTH	MA	41-56-27.4600N	070-38-48.8200W	PR						0.89	5,403	339.57

APPENDIX C
PAVE PAWS WIND TURBINE ANALYSIS

Wind Turbine Analysis for

Cape Cod Air Force Station Early Warning Radar

and Beale Air Force Base Upgraded Early Warning Radar

Spring 2007

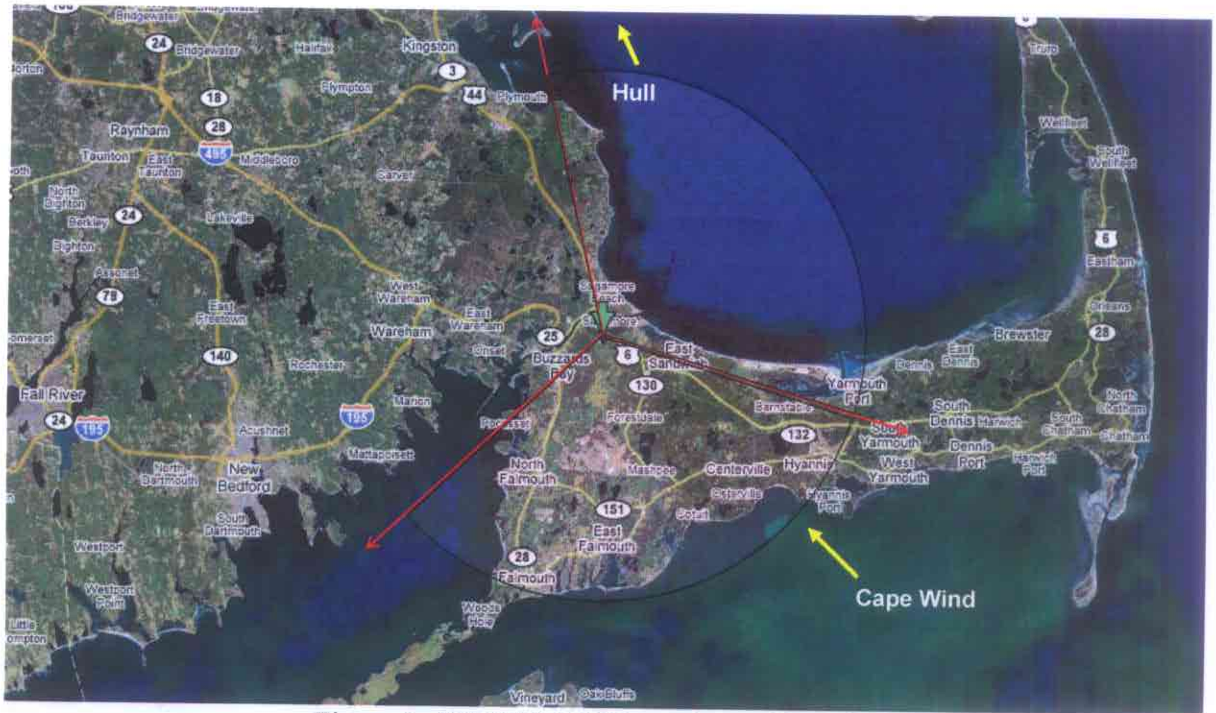


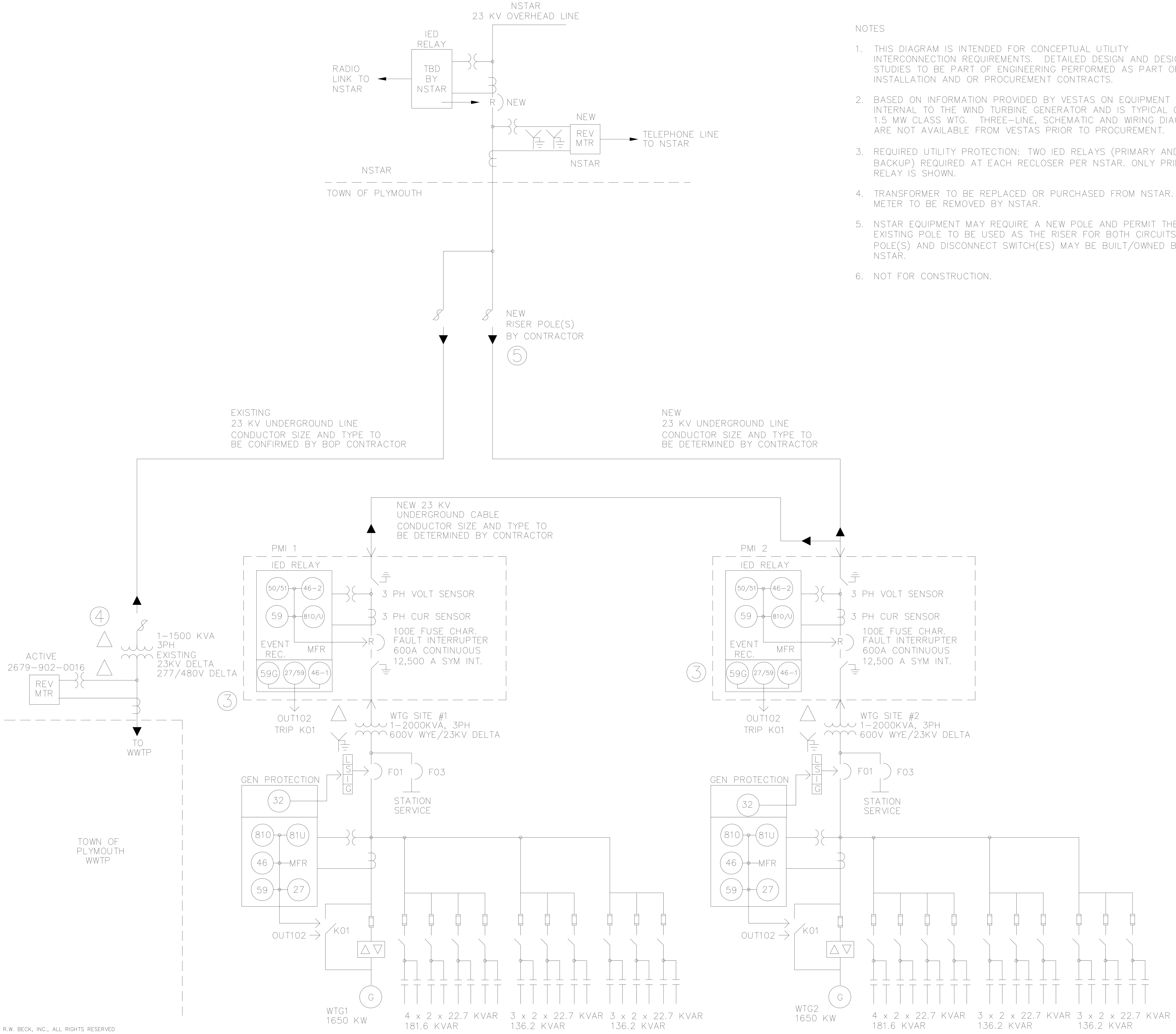
Figure 2. PAVE PAWS Location at Cape Cod

CONCLUSIONS AND RECOMMENDATIONS

The discussion above supports the following recommendations and conclusions applicable to placement of wind farms in the vicinity of Cape Cod AFS and Beale AFB.

- Utility class wind farms could have a significant impact on radars, including the missile defense early warning radars (EWRs), the PAVE PAWS radar at Cape Cod AFS, MA, and the Upgraded Early Warning Radar (UEWR) at Beale AFB, CA.
- To mitigate this impact, establish and enforce a wind farm offset zone within the effective "line-of-sight" of the radars, taking into account the direct, refracted, and diffracted signals from the radar. This effectively establishes a zone around the radar of approximately twenty-five kilometers, assuming relatively level terrain.
- Within twenty-five kilometers, further study would be required to assess the impact accounting for location within the radar's field of view and the relative height of the wind turbine and the radar's main beam.
- After establishing this offset zone, eliminate any remaining impacts on the radar by using gain control and range gating techniques.

APPENDIX D
ELECTRICAL ONE-LINE DIAGRAM



NOTES

1. THIS DIAGRAM IS INTENDED FOR CONCEPTUAL UTILITY INTERCONNECTION REQUIREMENTS. DETAILED DESIGN AND DESIGN STUDIES TO BE PART OF ENGINEERING PERFORMED AS PART OF INSTALLATION AND OR PROCUREMENT CONTRACTS.
2. BASED ON INFORMATION PROVIDED BY VESTAS ON EQUIPMENT INTERNAL TO THE WIND TURBINE GENERATOR AND IS TYPICAL OF A 1.5 MW CLASS WTG. THREE-LINE, SCHEMATIC AND WIRING DIAGRAMS ARE NOT AVAILABLE FROM VESTAS PRIOR TO PROCUREMENT.
3. REQUIRED UTILITY PROTECTION: TWO IED RELAYS (PRIMARY AND BACKUP) REQUIRED AT EACH RECLOSER PER NSTAR. ONLY PRIMARY RELAY IS SHOWN.
4. TRANSFORMER TO BE REPLACED OR PURCHASED FROM NSTAR. METER TO BE REMOVED BY NSTAR.
5. NSTAR EQUIPMENT MAY REQUIRE A NEW POLE AND PERMIT THE EXISTING POLE TO BE USED AS THE RISER FOR BOTH CIRCUITS. POLE(S) AND DISCONNECT SWITCH(ES) MAY BE BUILT/OWNED BY NSTAR.
6. NOT FOR CONSTRUCTION.

LEGEND

- CURRENT TRANSFORMER
- VOLTAGE TRANSFORMER
- NON FUSED SWITCH
- FUSED SWITCH
- FUSE
- PROTECTIVE RELAY
  ## = ANSI FUNCTION
  27 – UNDERVOLTAGE
  32 – REVERSE POWER
  46 – PHASE BALANCE CURRENT
  50 – PHASE INSTANTANEOUS CURRENT
  51 – PHASE TIME OVERCURRENT
  59 – OVERVOLTAGE
  59G – GROUND OVERVOLTAGE, 3V0
  60 – VOLTAGE IMBALANCE
  81O – OVERFREQUENCY
  81U – UNDERFREQUENCY
- INTELLIGENT ELECTRONIC DEVICE UTILITY INTERCONNECTION PROTECTION SEL-351 OR EQUIVALENT
- PLC GENERATOR PROTECTION
- POWER BREAKER WITH INTEGRATED OVERCURRENT PROTECTION
- INSULATED CASE CIRCUIT BREAKER
- ELECTRONIC VACUUM RECLOSER
- POWER TRANSFORMER
- SOFT SYNC THYRISTORS

BOP BALANCE OF PLANT
MFM MULTI FUNCTION METER
PMR PAD MOUNT INTERRUPTER
PMT PAD MOUNT TRANSFORMER

REV	DATE	DES	CK'D	APPROVALS	REVISION DESCRIPTION	REV	DATE	DES	CK'D	APPROVALS	REVISION DESCRIPTION

DES GM | DWN EED | CK'D PC | DATE 06-16-08

R.W. BECK — GEC GLOBAL ENERGY CONCEPTS

MASSACHUSETTS TECHNOLOGY COLLABORATIVE
PLYMOUTH WIND ENERGY FEASIBILITY STUDY
CONCEPTUAL ELECTRICAL
ONE-LINE DIAGRAM

FILE NO 11582
W/O 04-00989-0800
DWG NO 011582-ESK-10

APPENDIX E
PHOTO SIMULATIONS

Projection: UTM Zone 19, Meters, NAD27
Aerial Imagery: Office of Geographic and Environmental Information (MassGIS)
Property Boundary: MassGIS Parcel Map

Figure C-1. Photo visualization vantage points and the proposed wind turbine site

Figure C-2. Photo Simulation from Viewpoint 1 – Mall Looking East-Southeast

Figure C-3. Photo Simulation from Viewpoint 2 – Serendipity Farm Looking Northwest

Figure C-4. Photo Simulation from Viewpoint 3 – Tourist Information Center Looking Southwest
[Note: The wind turbines would not be visible from this vantage point; the turbine outlines are shown to illustrate the location of the turbines behind the obstructions.]

Figure C-5. Photo Simulation from Viewpoint 4 – Plymouth Rock Park Looking Southeast
[Note: The wind turbines would not be visible from this vantage point; the turbine outlines are shown to illustrate the location of the turbines behind the obstructions.]

Figure C-6. Photo Simulation from Viewpoint 5 – Plymouth Beach Looking South-Southwest [Note: The wind turbines would not be visible from this vantage point; the turbine outlines are shown to illustrate the location of the turbines behind the obstructions.]

APPENDIX F
PLYMOUTH WIND BYLAW & SPECIAL PERMITS BYLAW

§ 205-7. Associate member of Planning Board. [Added 4-23-1990 ATM by Art. 27]

A. The Planning Board may appoint a Planning Board associate member for the purpose of acting on special permit applications. The associate member shall be appointed annually. The associate member may be removed for cause by the Planning Board following written charges and a public hearing. Should the associate member position become vacant, it shall be filled forthwith by the Planning Board for the unexpired term.

B. The Planning Board Chairman may designate the associate member to sit on the Board for purposes of acting on a special permit application in case of:

(1) The absence of a regular member.

(2) The inability of a regular member to act.

(3) A conflict of interest of a regular member.

(4) A vacancy on the Board.

§ 205-8. Electronic plan formatting. [Added 4-7-1999 ATM by Art. 29]

A. **Special permit plan requirements.** All special permit uses and special permit uses subject to environmental design conditions shall submit as-built plans in electronic format compatible with standards to be established by the Town.

§ 205-9. Special permits.

A. **Procedures.** [Amended 4-5-1977 ATM by Art. 46; 4-6-1978 ATM by Art. 59; 4-20-1982 ATM by Art. 46; 4-4-1988 ATM by Art. 53; 4-10-1989 ATM by Art. 33]

(1) The special permit granting authority may grant a special permit for certain uses and structures as authorized in Articles III, IV, V and VI of this bylaw, subject to conditions and procedures set forth herein and in other applicable sections of the bylaw.

(2) Following application to the Building Inspector for a zoning permit, the applicant shall file a request for a special permit with the Town Clerk. Copies of the application, including the date and time of filing, certified by the Town Clerk, shall be filed forthwith by the applicant with the appropriate special permit granting authority and such officer or board whose order or decision is being appealed. Application for a special permit shall be filed with required number of copies indicated on forms provided by the special permit granting authority and should include any plans or other documents advised previously by the Building Inspector. The special permit granting authority may require additional information as necessary to adequately judge the merits of the request.

(3) Applications for special permits shall be distributed immediately to the Planning Board, the Design Review Board, Fire Chief, Board of Health, and the appropriate Village Steering Committee. The reports of the Design Review Board, Board of Health, and Village Steering Committee, which are advisory, shall be submitted to the Planning Board within 21 days of filing of the applications. The Planning Board shall transmit all such advisory reports to the Board of Appeals within 35 days of the filing of the applications. [Amended 4-10-2001 ATM by Art. 21]

(4) Within 30 days of filing of a special permit with the Board of Appeals, the Planning Board shall evaluate the proposal with regard to the conditions and standards set forth herein and

in the rules of the Board of Appeals and shall submit an advisory report in writing to the Board of Appeals. The Planning Board shall forward, with its report, copies of all recommendations received from other boards, commissions or departments. The Planning Board shall send a copy of its full report and recommendations, including copies of those received by it, to the applicant. The Board of Appeals shall not render a decision without considering the report of the Planning Board unless 30 days expire without the receipt of such report.

(5) A public hearing shall be held as prescribed in § 205-6B.

(6) The special permit granting authority shall make a decision on the special permit within 90 days following a public hearing for which notice has been given. The time limit for public hearings and taking of action by the special permit granting authority may be extended by written agreement between the petitioner and the special permit granting authority, with a copy filed with the Town Clerk. With respect to each special permit, the special permit granting authority shall establish a reasonable period, not to exceed two years, after which, if substantial use or construction permitted by the permit has not been commenced and is not continued, the special permit shall expire. This time period will begin on the date on which the permit is filed with the Town Clerk. The time period shall automatically be extended by the amount of time required to pursue and await the determination of an appeal.

(7) Decision.

(a) The decision of the special permit granting authority shall be distributed as follows:

[1] Copies of its decision together with the detailed reasons therefor shall be filed with the Town Clerk, the Planning Board and the Building Inspector;

[2] A certified copy of its decision shall be mailed to the owner and to the applicant if other than the owner;

[3] A notice of the decision shall be sent to the parties of interest and to persons who requested a notice at the public hearing.

(b) In addition, copies of the detailed records of the proceedings indicating the vote of each member and setting forth the reasons for said vote shall be filed at the office of the Town Clerk within 14 days of said decision and all of the above shall be completed within 90 days after the public hearing date.

(8) No special permit shall take effect until notice of approval is recorded with the title of the land in question in the Plymouth County Registry of Deeds or the Plymouth Land Registry District and until a certified copy of said recording is transmitted to the Board of Appeals by the Registry. The responsibility and the cost of said recording and transmittal shall be borne by the owner of the land in question. A petitioner who seeks approval because of the special permit granting authority's failure to act on an appeal, variance, or special permit must notify the Town Clerk in writing, within 14 days from the expiration of said time limit for a decision, of such approval and that notice be sent by the petitioner to the parties in interest by mail which shall specify that appeals, if any, shall be made pursuant to MGL c. 40A, § 17 and shall be filed within 20 days after the date of filing the request for approval with the Town Clerk by the petitioner.

B. **Conditions and safeguards.**

(1) The Board of Appeals shall not grant any special permit unless necessary conditions are satisfied, including but not limited to the following: [Amended 5-13-1981 ATM by Art. 36; 4-10-2001 ATM by Art. 21]

(a) The proposed use is appropriate in the zone and specific site in question, more particularly to promote the most appropriate use of land throughout the Town in accordance with a Comprehensive Plan;

(b) Adequate and appropriate facilities will be provided for proper operation of said use;

(c) There will be no hazard to pedestrians or vehicles;

(d) There will be no nuisance or adverse effect upon the neighborhood;

(e) In the case of high technology planned unit developments the requirements of § 205-28 and particularly § 205-28D, Overall planning principles and requirements, are fully satisfied.

(2) The Board of Appeals may require conditions and safeguards deemed necessary to protect the neighborhood or the Town, including but not limited to the following:

(a) Requirement of front, side or rear yards greater than the minimum otherwise prescribed by this bylaw;

(b) Requirement of screening of service or parking areas or other areas of the site by walls, fences, planting, or other approved means;

(c) Limitation of signs or other advertising features;

(d) Limitations of number or density of occupants, times or nature of operation, size, scale, or other characteristics of use or facilities;

(e) Regulation of the number, design and location of access drives or circulation facilities;

(f) Requirements of off-street parking, loading or other features beyond the minimum otherwise required by this bylaw;

(g) Requirement that developments be done in stages or that appropriate Town or private services and facilities are available prior to the issuance of a building permit for any part of the proposed development. In the case of high technology planned unit developments, these required services shall include, but not be limited to, streets, their traffic-carrying capacity between the site and a limited access highway, water supply and distribution system, solid waste disposal facilities, electric, gas and telephone services, fire and police protection service, sewage disposal facilities, and surface water drainage. [Added 4-2-1974 ATM by Art. 69; amended 5-13-1981 ATM by Art. 36]

(h) Requirement that adverse effect, if any, to the subterranean water table and to the ecology in the vicinity of the proposed development be minimized to the extent possible. [Added 4-22-1974 ATM by Art. 69]

C. **Environmental design conditions.**

(1) **Intent.** For certain uses prescribed in each zoning district in Articles IV, V and VI and in § 205-27, the Board of Appeals shall not grant any special permit unless additional environmental design conditions are satisfied. This section is intended to provide a detailed review by the Board of Appeals aided by appropriately qualified Town boards and their consultants of such uses which have a significant impact upon the health, safety and general welfare of the Town and it inhabitants due to their location, intensity of use, scale of structures, traffic generation, impact upon the landscape and natural ecological processes, visual prominence, social and cultural importance to the Town, and overall impact upon the character and environmental amenity of Plymouth. Upon receipt of an application for special permit normally subject to the conditions and safeguards set forth in Subsection B of this section, the Board of Appeals may determine that, due to the location, complexity, scale, or characteristics of operation of the use in question, it should be subject to the additional environmental design conditions specified herein.

(2) **Administration of environmental design conditions.** [Amended 4-17-1975 ATM by Art. 68; 4-6-1978 ATM by Art. 59; 5-20-06 ATM by Art. 25]

(a) Procedures shall be the same as prescribed in Subsection A of this section for all special permits except that more detailed review shall be needed, additional information shall be provided on plans, with required number of copies indicated on forms provided by the special permit granting authority and should include any plans or other documents advised previously by the Building Inspector. The special permit granting authority may require additional information as necessary to adequately judge the merits of the request. The Board of Appeals shall distribute the plans to the Planning Board, Design Review Board, Building Inspector, Conservation Commission, Town Engineer, Department of Public Works, Board of Selectmen, Fire Chief, Board of Health, and other departments, agencies, boards, and commissions as may apply.

(b) Any of these boards or officials desiring to offer advisory comments shall submit a report in writing to the Planning Board within 21 days. The Planning Board shall submit its advisory report to the Board of Appeals as normally prescribed in Subsection A of this section. The Planning Board shall submit its report and recommendations together with copies of all other reports and recommendations received by it to the Board of Appeals and the applicant as normally prescribed in Subsection A.

(3) **Information required.**

(a) The plan submitted shall be titled "preliminary plan" and shall be accurately drawn to a scale of one inch equals 20 feet, one inch equals 40 feet or one inch equals 100 feet where practical and appropriate to the size of the proposal.

(b) There shall be submitted at the same scale as the site plan a professionally surveyed plan of existing site features, including the size of the property, the topography at two-foot contour intervals, general soil types, vegetation cover, including accurate locations of wooded areas and major trees (see § 205-18), as well as roads, structures or other significant features. A locus map shall be included to indicate the location of the property within the Town. For small sites or projects of a relatively simple nature, this information may be provided on the site plan [see Subsection C(3)(d) below] at the discretion of the Board of Appeals. Photographs of representative portions of the site at a size of eight inches by 10 inches (copies to

Board of Appeals, Planning Board and Design Review Board only) shall be included.

(c) In order to allow adequate consideration of the surroundings, a plan of adjacent properties shall be presented at a scale of not less than one inch equals 100 feet or at the same scale as the proposed site plan if practical. This plan shall show the general characteristics of all lands within 200 feet of the proposed site or such other distance as may be reasonably required, including structures, parking areas, driveways, pedestrianways, and natural characteristics. Any structures or significant change in topography within 50 feet of the lot line shall be located precisely on said plan.

(d) A site plan and any other drawings necessary shall precisely indicate the area of the site; the proposed uses of the land; the vehicular circulation system, including pavement widths, right-of-way, and how the system relates to the surrounding street pattern; all parking and required screening; the pedestrian circulation system and other pedestrian facilities and how they relate to surrounding pedestrian circulation; all proposed structures, including their exact location, relation to the topography, plan configuration, height, bulk, materials, elevations, and other necessary design information; the number and type of dwelling units, if any, and their density or land use intensity within specific clusters and over the entire site; service access and facilities for all structures or uses, including garbage and trash disposal facilities; the location of all open space, including its intended use, natural trees and foliage to be maintained, specific new planting by size and location, finish contours of the topography and an indication of types of ground cover and other precautions to stabilize all slopes; all site drainage, including natural courses and storm drains; significant site appurtenances such as walls, light poles, recreation areas and facilities; and any other items reasonably prescribed by the Board of Appeals.

(e) In order to evaluate the impact of the proposed development on Town services and the welfare of the community, there shall be submitted an impact statement which describes the impact of the proposed development on all applicable Town services, including but not limited to schools, sewer system, water system, parks, playgrounds, and fire and police protection; the projected generation of traffic on the roads of and in the vicinity of the proposed development; the subterranean water table, including the effect of proposed septic systems; and the ecology of the vicinity of the proposed development. The impact statement shall also indicate the means by which Town or private services required by the proposed development will be provided, such as by private contract, extension of municipal services by a warrant approved at Town Meeting, recorded covenant, or by contract with a homeowners' association. [Added 4-22-1974 ATM by Art. 69]

(f) Where appropriate there shall also be submitted any drawings or documents necessary to establish the feasibility of proposals for water supply, waste and storm water disposition, the feasibility of planting proposals, and all easements or restrictions to be proposed for open space, utilities or other purposes.

(g) In rendering a decision, the Board of Appeals shall title the plan a "definitive plan" and mark the same as approved, approved with conditions, or disapproved.

(4) **General conditions and standards.** All developments subject to environmental design conditions shall be designed and evaluated with consideration for the following general standards as well as specific standards prescribed in other sections or in the rules of the Board of Appeals.

(a) **Natural features conservation.** Disruption of existing site features, including particularly the clearing of trees and undergrowth and the changing of natural topography, shall be kept to an absolute practical minimum. Where tree coverage does not exist or has been removed, new planting may be required. Finish site contours shall approximate the character of the natural site and surrounding properties. See § 205-18 and sections concerning specific land uses.

(b) **Relation to surroundings.** The location, scale, and characteristics of proposed land uses on the site; the design, siting, and scale of structures; and the circulation and other characteristics of the development shall be in harmony with surrounding properties and land uses.

(c) **Vehicular and pedestrian circulation.** Pedestrian walkways, streets, driveways, and parking areas shall be carefully designed with respect to topography, proper relation to surrounding streets and pedestrianways, number of access points to public streets, provision of a clear and efficient street system on the site, adequate widths of drives and street, separation and attractive parking areas, and proper relationship of circulation elements to structures and other site features.

(d) **Siting of structures.** All buildings and other structures shall be sited to minimize disruption of the topography and to facilitate natural surface drainage and shall be properly designed for the particular site conditions. Strict attention shall be given to proper functional, visual, and spatial relationship of all structures, landscape elements, and paved areas.

(e) **Design of structures.** All structures shall be of high design and construction quality and shall be compatible with the neighborhood and the Town as to design characteristics, including but not limited to scale, massing, proportions, height, roofs, colors, and materials. Use of any particular historical style of architecture is not encouraged.

(f) **Surface water drainage.** All surface water drained from roofs, streets, parking lots and other site features shall be disposed of in a safe and efficient manner which shall not create problems of water runoff or erosion on the site in question or on other sites. Insofar as possible natural drainage courses, swales properly stabilized with plant materials or paving when necessary, and drainage impounding areas shall be utilized to dispose of water on the site through natural percolation.

(g) **Utilities.** All electrical utility lines, including but not limited to telephone, power, and cable television, shall be placed underground in new developments. The installation shall be done in accordance with the specifications of the utility company concerned and shall be subject to all applicable provisions of its terms and conditions of service as filed with the Department of Public Utilities of the Commonwealth of Massachusetts. The placement of electrical lines and other underground utility lines, such as water, sewerage and gas, shall be coordinated whenever possible and desirable. Placement of utilities, including sanitary sewers and disposal facilities, shall be done so as to minimize disruption of topography and cutting of trees or undergrowth. The proposed method of sanitary sewage disposal shall be shown precisely on plans.

(h) **Signs.** Signs and outdoor advertising features shall be subject to the regulations of § 205-19, Signs. Such signs shall be reviewed as an integral element in the design and

planning of all developments and shall be in harmony with the proposed and nearby developments.

(i) **Other site features.** All service areas, loading areas, outdoor storage, utility structures, mechanical equipment, garbage disposal facilities, or other service or utility facilities shall be located or visually screened so as not to create hazards or visual or other nuisances. Light fixtures, walls, fences, benches, recreation facilities and other such site appurtenances shall be harmoniously designed, constructed, and located in relation to other site features.

(5) **Specific standards.**

(a) In addition to the preceding general standards and design criteria, more specific requirements and design criteria are prescribed under the district regulations for each zoning district in Articles IV, V and VI and under the following sections:

[1] Natural features conservation requirements: § 205-18.

[2] Protection of open space quality: §§ 205-19 and 205-20.

[a] Signs: § 205-19.

[b] Wires and poles: § 205-20.

[3] Buffers between land uses: § 205-21.

[4] Off-street parking: § 205-23.

[5] Off-street loading: § 205-24.

[6] Special permit uses: § 205-27.

[7] Planned unit development: § 205-28.

(b) The Board of Appeals shall adopt rules to aid in the conduct of its duties which may include additional conditions and safeguards which supplement those prescribed in this section or the above section. Such rules shall be available to the public.

(6) **Modification of criteria for excellence of design.** The environmental design conditions described herein embody the basic goals of the Zoning Bylaw. They are intended to minimize the possibility of poor design and site planning and therefore to ensure that the character of specific developments is, in fact, consistent with the overall development objectives of the Town and the particular neighborhood. These principles are intended as general tools for use by the Board of Appeals and Planning Board in reviewing projects and are not to be seen as inflexible standards. These guidelines are not to be applied in a manner which will place undue restraints upon the design of a project because of unforeseen conditions peculiar to such project. If a particular development is proposed which departs from the general criteria in basic concept or in detail, the Board of Appeals may waive or modify the general criteria upon a demonstration that the proposed design is of high standards and that any departures from the general criteria will not violate the intent of the Zoning Bylaw or the environmental design conditions.

D. **Adequate facility conditions.** In addition to the preceding standards and design criteria, provisions relative to adequate facilities are as provided for in § 205-67. [Added 4-7-1987 ATM by Art. 69]

adult dance clubs, including entertainment establishments allowing one or more individuals to perform the state of nudity, as defined under G.L. c. 272 §31

§ 205-73 Wind Energy Facilities [Added 10-24-05 FTM by Article 22; Amended 10-23-06 FTM by Art. 32]

A. Purpose. The purpose of this bylaw is to encourage by special permit the use of wind energy and to minimize the impacts of wind facilities on the character of neighborhoods, on property values, on the scenic, historic, and environmental resources of the Town; and to protect health and safety, while allowing wind energy technologies to be utilized.

B. Definitions.

WIND FACILITY - All equipment, machinery and structures utilized in connection with wind-generated energy production and generation, including accessory transmission, distribution, collection, storage or supply systems whether underground, on the surface, or overhead and other equipment or byproducts in connection therewith and the sale of the energy produced thereby, including but not limited to, wind turbine (rotor, electrical generator and tower) and accessory anemometers (wind measuring equipment), transformers, substation, power lines, control and maintenance facilities, site access and service roads.

WIND FACILITY, MUNICIPAL - A wind facility located on town owned property which is designed to provide its electrical output, or of the value thereof, for the use or benefit of the town and without regard to the ownership of the structure or equipment. A third party may own and operate with an agreed upon financial percentage of revenues benefiting the town.

CAPACITY FACTOR - The wind turbine's actual energy output for the year divided by the energy output if the machine operated at its rated power output for the entire year.

C. Location and area requirements.

A wind facility may be erected by special permit subject to Environmental Design Conditions on land that contains a minimum of five (5) acres. The SPGA (Special Permit Granting Authority) may allow more than one wind turbine if it determines that the location is favorable to the clustering of wind turbines.

D. Planning Principles and design requirements.

Unless otherwise expressly provided by this section of the bylaw all requirements of the underlying zoning district shall apply and in addition the following design standards shall apply:

(1) All equipment necessary to monitor and operate the wind facility should be contained within the turbine tower unless technically infeasible. In which case, ancillary equipment may be located outside the tower, provided it is contained either within an underground vault, or enclosed within a separate structure or behind a year-round landscape or vegetated buffer.

(2) All utility connections from the wind facility site shall be underground except to the extent that underground utilities are not feasible in the determination of the SPGA. Electrical transformer for utility interconnections may be above ground if required by the utility provider.

(3) Clearing of natural vegetation shall be limited to that which is necessary for the construction, operation and maintenance of the wind facility.

(4) Wind turbines shall be lighted only if required by the Federal Aviation Administration (FAA). The proponent shall provide a copy of the FAA's determination to establish the required markings and/or lights for the structure. Lighting of equipment structures and any other facilities on site (except lighting required by the FAA) shall be shielded from abutting properties.

(5) The wind facility shall be set back no less than a distance equal to the overall height of the wind turbine from the nearest lot line and shall be a minimum of 100 feet from any lot line. For purposes of calculating setbacks, the overall height of a wind turbine, the total height shall be measured from the average natural grade within the footprint of the supporting structure, to the uppermost extension of any blade or other part of the wind turbine.

(6) Wind facilities shall have a maximum height of 350-feet, as measured from the natural grade to the top of the hub were the rotor attaches.

(7) Wind facilities shall be a neutral, non-reflective color designed to blend with the surrounding environment.

(8) Noise. Except during short-term events such as high windstorms or utility outages, noise from the proposed wind turbine shall not exceed 60 dBA as measured from the nearest property line. This standard may be met through a 600-foot setback from the nearest property line. Reductions may be granted by the SPGA if the applicant can demonstrate through scientific analysis that the noise levels will not exceed 60 dBA at the property line.

(9) Shadowing/Flicker. The wind facility shall be sited in a manner that does not result in significant shadowing or flicker impacts. The proponent has the burden of proving that this effect does not have significant adverse impact on neighboring or adjacent uses either through siting or mitigation.

(10) Removal. The owner or his successors in interest shall remove any wind facility the use of which has been discontinued. At the time of removal, the wind facility site shall be restored to its natural state or to any other legally authorized use. All wind turbines and appurtenant structures shall also be removed. The SPGA shall require that escrow account or other suitable surety be established to ensure adequate funds are available for removal. Municipal wind facilities shall be exempt from the surety requirement. The amount of such surety shall be equal to 150 percent of the cost of compliance with this section. The applicant shall submit a fully inclusive estimate of the costs associated with removal, prepared by a qualified engineer. The amount shall include a mechanism for a Cost of Living Adjustment after 10 and 15 years.

(11) The wind facility shall be designed to prevent unauthorized site access.

E. Administration.

For this Section of the Zoning Bylaw, the Zoning Board of Appeals shall be the special permit granting authority (SPGA). In reviewing a Wind Facility, the SPGA shall be governed by the special permit and environmental design conditions and procedures as specified in § 205-9.

A special permit may be granted under this section if the SPGA finds that each of the design standards set forth have been met and that

1. There is no feasible alternative to the proposed height,
2. It is the minimum necessary
3. There is a clear and specific public benefit which may be realized only be exceeding 35 feet in height, and
4. The proposed structure will not in any way detract from the visual character or quality of the adjacent buildings, the neighborhood, or the Town as a whole.

The SPGA may impose, in addition to any applicable conditions specified in this section, such conditions as it finds reasonably appropriate to safeguard the neighborhood or otherwise serve the purposes of this section, including, but not limited to: screening, lighting, fences, modification of the exterior appearance of the structures, limitation upon size, method of access or traffic features, parking, removal upon cessation of use or other requirements.

The applicant must demonstrate that the wind facility operates at a capacity factor in excess of 25 percent.

The SPGA may require the proponent to provide or pay for professional consultants to evaluate the proposal to determine the acceptability of geographic location, to analyze the loading capacities of the proposed structures, and to review camouflage and screening techniques.

F. Application for Special Permit. The following information must be submitted for an application to be considered complete:

(1) A locus plan at a scale of 1" = 200' which shall show all property lines, the exact location of the proposed structure(s), street landscape features, dwellings and other structures within one-hundred (100) feet of the property line.

(2) A one-inch-equals-40 feet vicinity plan, signed and sealed by a Registered Professional Engineer or Licensed Surveyor showing the following:

a) Property lines for the subject property and all properties adjacent to the subject property within 300 feet.

b) Outline of all existing buildings, including purpose (e.g., residential buildings, garages, accessory structures, etc.) on subject property and all adjacent properties within 300 feet. Distances, at grade, from the proposed wind facility to each building on the vicinity plan shall be shown.

c) Proposed location of the wind facility, including all turbines, fencing, associated ground equipment, transmission infrastructure and access roads.

(3) Location of all roads, public and private, on the subject property and on all adjacent properties within 300 feet including driveways proposed to serve the wind facility.

(4) All proposed changes to the existing property, including grading, vegetation removal and temporary or permanent roads and driveways,

(5) Representations, dimensioned and to scale, of the proposed facility, including cable locations, parking areas and any other construction or development attendant to the wind facility.

(6) Tree cover and average height of trees on the subject property and adjacent properties within 300 feet.

(7) Contours at each two feet Above Mean Sea Level (AMSL) for the subject property and adjacent properties within 300 feet.

(8) Representation of location of viewpoint for the sight-line diagram referenced below.

(9) Sight lines and photographs.

a) Sight-line representation. A sight-line representation shall be drawn from representative locations that show the lowest point of the turbine tower visible from each location. Each sight line shall be depicted in profile, drawn at one inch equals 40 feet. The profiles shall show all intervening trees and buildings. There shall be at least two sight line representations illustrating the visibility of the facility from surrounding areas such as the closest habitable structures or nearby public roads or areas.

b) Existing (pre-development) photographs. A color photograph of the current view shall be submitted from at least two locations to show the existing situation.

c) Proposed (post development). Each of the existing-condition photographs shall have the proposed wind facility superimposed on it to accurately simulate the proposed wind facility when built and illustrate its total height, width and breadth.

(10) Elevations. Siting elevations, or views at-grade from the north, south, east and west for a 50-foot radius around the proposed wind facility.

(11) Materials.

a) Manufacturer's specifications for the proposed wind facility shall be provided for all equipment and attendant facilities.

b) Component materials of the proposed wind facility specified by type and specific treatment.

c) Colors of the proposed wind facility represented by a color board showing actual colors proposed.

(12) Landscape plan. A Landscape plan including existing trees and shrubs and those proposed to be added or removed, identified by size of specimen at installation and species.

(13) Other requirements.

a) Confirmation that the wind facility complies with all applicable Federal and State standards.

b) If applicable, a written statement that the proposed wind facility complies with, or is exempt from applicable regulations administered by the Federal Aviation Administration (FAA), Massachusetts Aeronautics Commission and the Massachusetts Department of Public Health.

c) Within 30 days of the pre-application conference, or within 21 days of filing an application for a Special Permit, the applicant shall arrange for a balloon or crane test at the proposed site to illustrate the height of proposed facility. The date, time an location of such test shall be advertised in a newspaper of general circulation in the town at least 14 days, but not more than 21 days prior to the test.

§ 205-74. Cordage Park Smart Growth District (CPSGD) [Added 5-20-06 SPTM by Article 13].

A. **Purposes.** The purposes of the Cordage Park Smart Growth District are:

(1) To provide an opportunity for residential and mixed-use development within a distinctive, attractive and livable environment that supports the commercial revitalization of Cordage Park and the North Plymouth Village Service Area.
(2) To promote continuing development and redevelopment in Cordage Park that is pedestrian friendly and consistent with Plymouth history and architecture.
(3) To ensure high quality site planning, architecture and landscape design that enhances the distinct visual character and identity of North Plymouth and provides an environment with safety, convenience and amenity.
(4) To provide for a diversified housing stock at a variety of costs within walking distance of the North Plymouth Village Service Area and the Plymouth commuter rail station, including affordable housing, and in housing types that meet the needs of the Town's population.
(5) To generate positive tax revenue, and to benefit from the financial incentives provided by M.G.L. c.40R, while providing the opportunity for new business growth and additional local jobs.

B. **Scope and authority.** The Cordage Park Smart Growth District is established pursuant to the authority of M.G.L. c.40R and 760 CMR 59.00, and shall be deemed to overlay the parcels as shown on the Zoning Map of the Town of Plymouth, as amended. The applicant shall have the option of applying for Site Plan Approval pursuant to the zoning controls set forth in this § 205-74, or complying with all applicable zoning controls set forth in the Zoning Bylaw of the Town of Plymouth for the underlying LI/WF District. Development Projects proceeding under this § 205-74 shall be governed solely by the provisions of this § 205-74 and shall be deemed exempt from the standards and/or procedures of the Underlying Zoning.

C. **Definitions.** As used in this section, the following terms shall have the meanings set forth below:

AFFORDABLE HOUSING RESTRICTION – A deed restriction of an Affordable Unit meeting statutory requirements in M.G.L. c.184 § 31 and the requirements of § 205-74(L) of this Bylaw.

AFFORDABLE RENTAL UNIT – A dwelling unit required to be rented to an Eligible Household per the requirements of § 205-74(L) of this Bylaw.

AFFORDABLE HOMEOWNERSHIP UNIT – A dwelling unit required to be sold to an Eligible Household per the requirements of § 205-74(L) of this Bylaw.